quarterly analysis review

17.4

4Q 2017

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nrel	aaron brooker, jeff gonder, marc melaina, matteo muratori, mark singer, eric wood
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sra/sentech	russ campbell, karen sikes

18 december 2017

topics

1 energy markets

automotive markets

technologies studies

environmental studies

behavior & opinion surveys

policy & business studies

qar

outline

1 energy markets

vehicle fuels

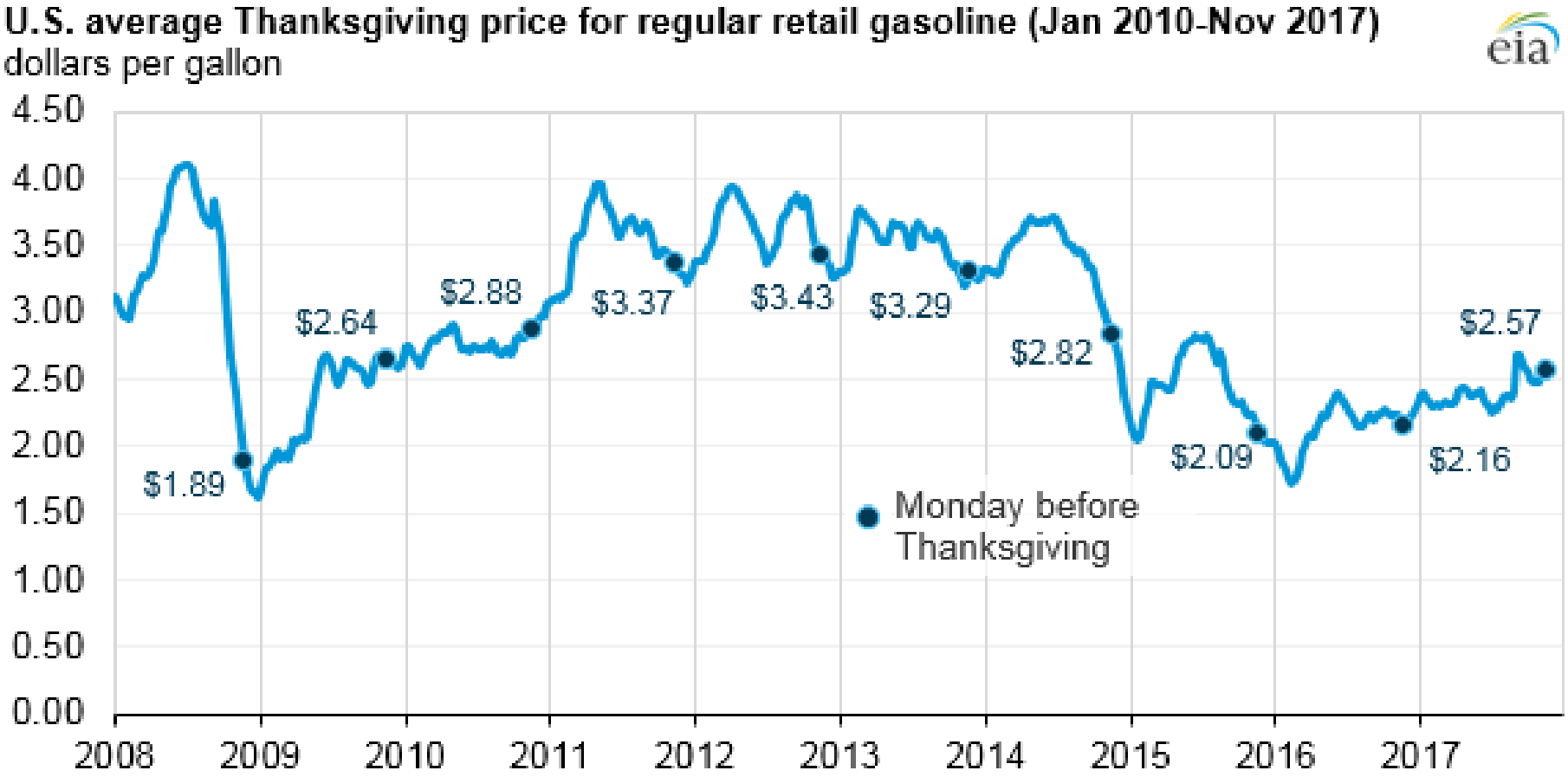
> EIA: Gasoline prices for Thanksgiving were higher than previous two years

energy markets/production

> FOTW: U.S. petroleum production met domestic transportation demand in 2015
> FOTW: Transportation is responsible for over 70% of domestic petroleum consumption in the U.S.
> OPEC, ExxonMobil, IEA: Demand for petroleum will grow in next decades, driven especially by developing countries
> FOTW: Trade deficit for petroleum products is at lowest point in two decades

gasoline prices

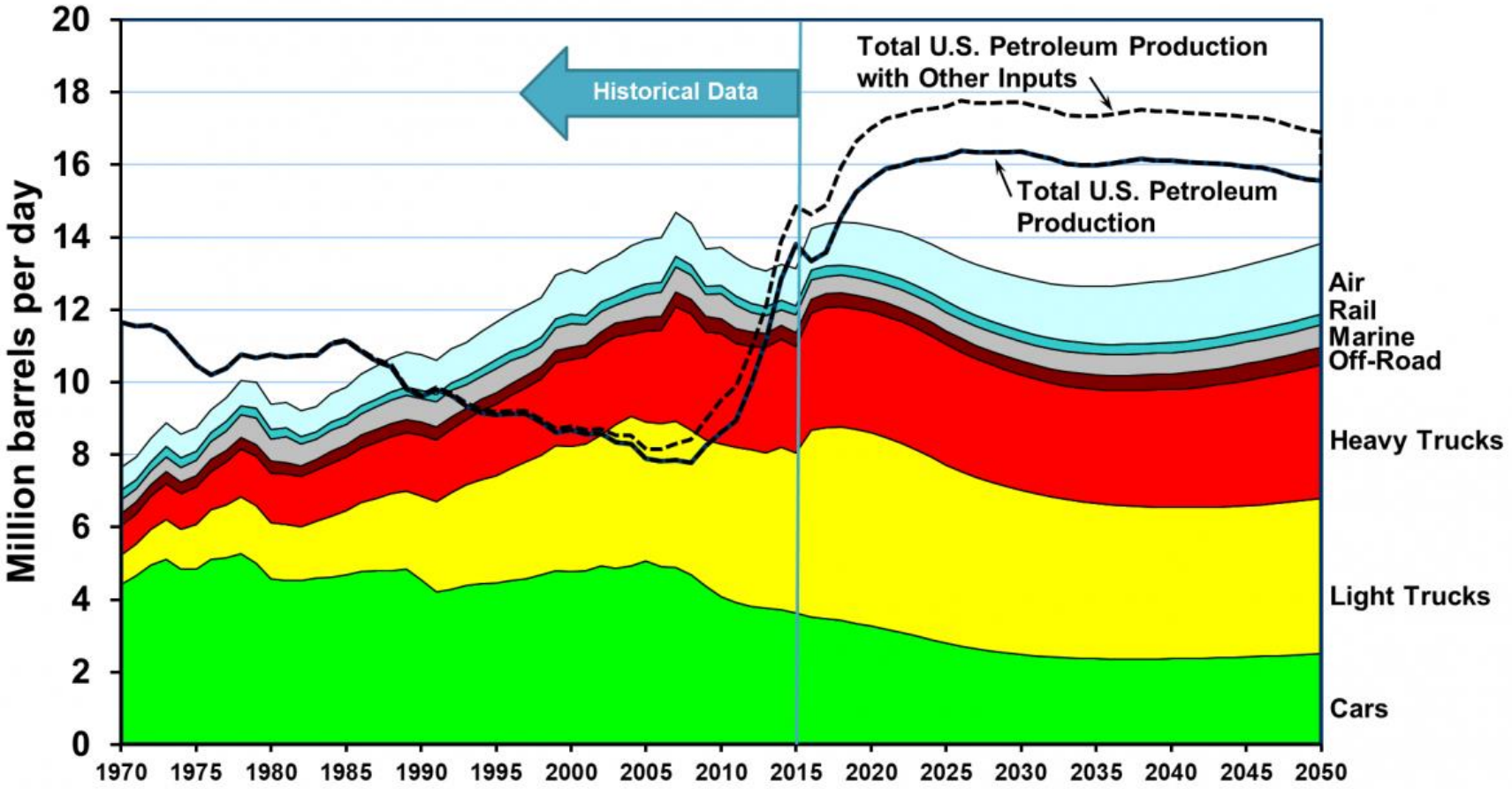
EIA: Thanksgiving average gasoline prices were higher than the previous two years



Source: https://www.eia.gov/todayinenergy/detail.php?id=33852

oil consumption and production

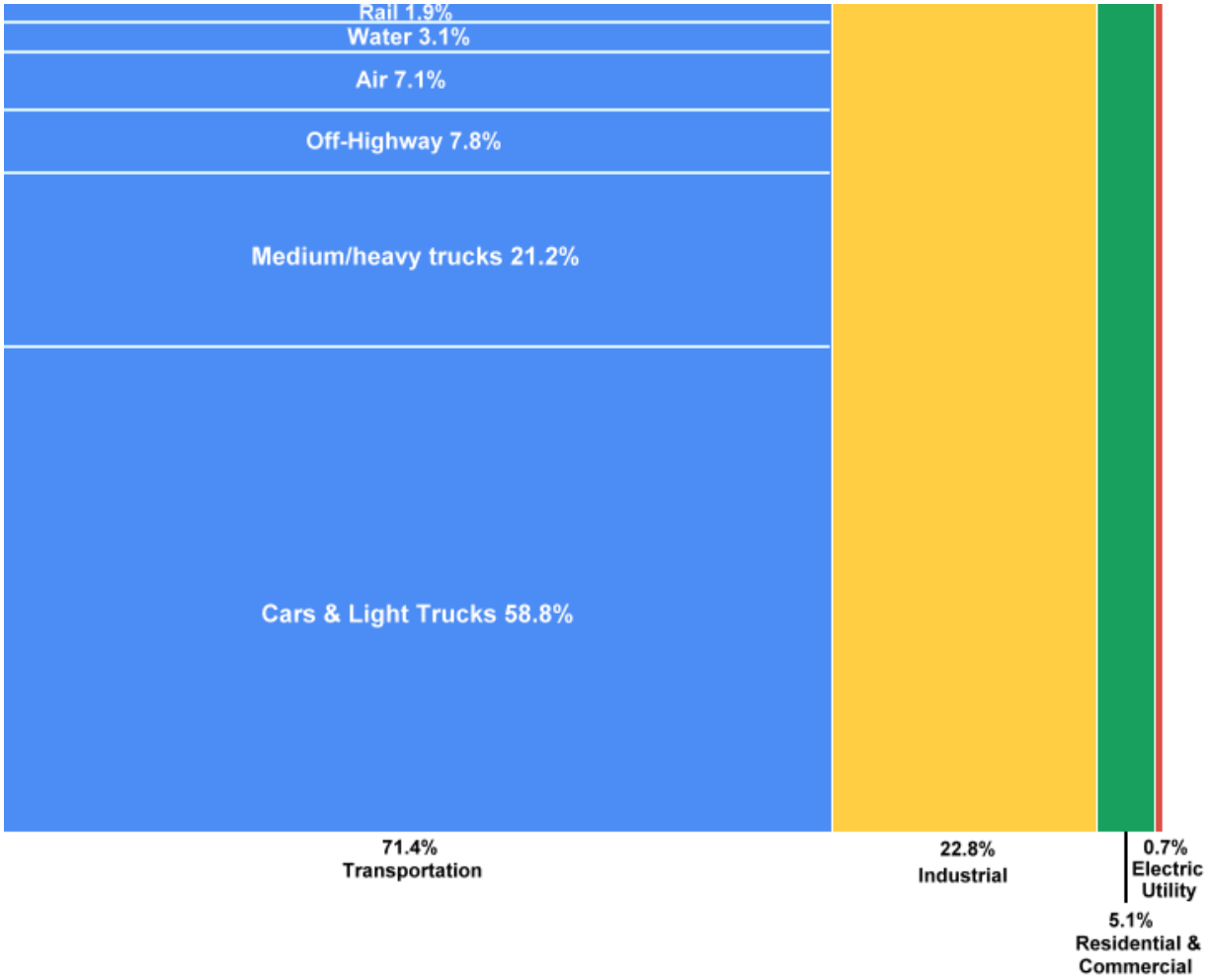
FOTW: U.S. petroleum production met domestic demand from transportation in 2015



Source: https://energy.gov/eere/vehicles/articles/fotw-1000-october-23-2017-us-petroleum-production-met-demand-transportation

oil consumption

FOTW: Transportation is responsible for over 70% of domestic petroleum consumption in the U.S.

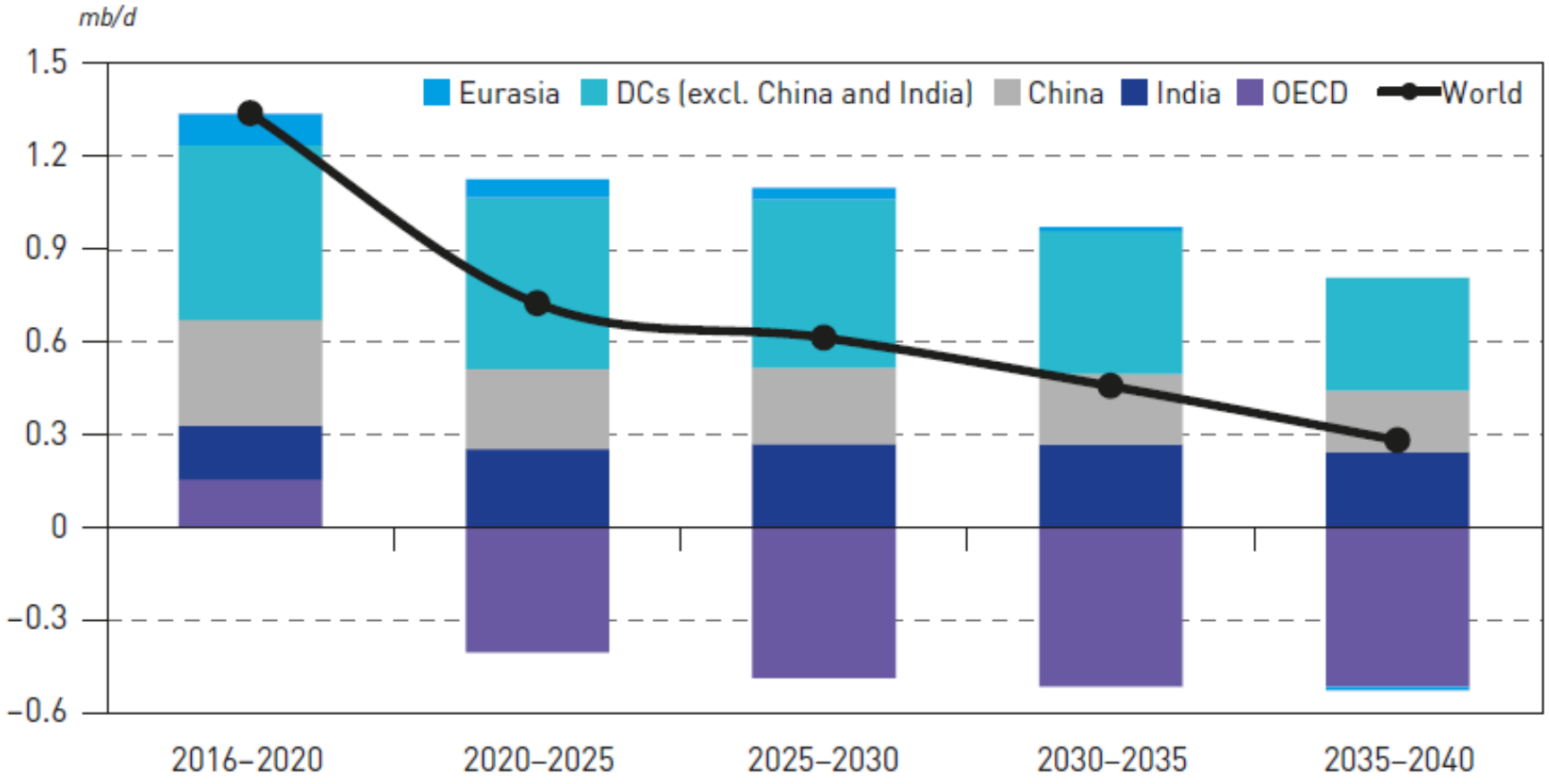


Source: https://energy.gov/eere/vehicles/articles/fact-996-september-25-2017-transportation-accounts-nearly-three-quarters

oil consumption

OPEC: Oil demand growth through 2040 will be driven by developing countries (including China and India)

Average annual oil demand growth in the Reference Case

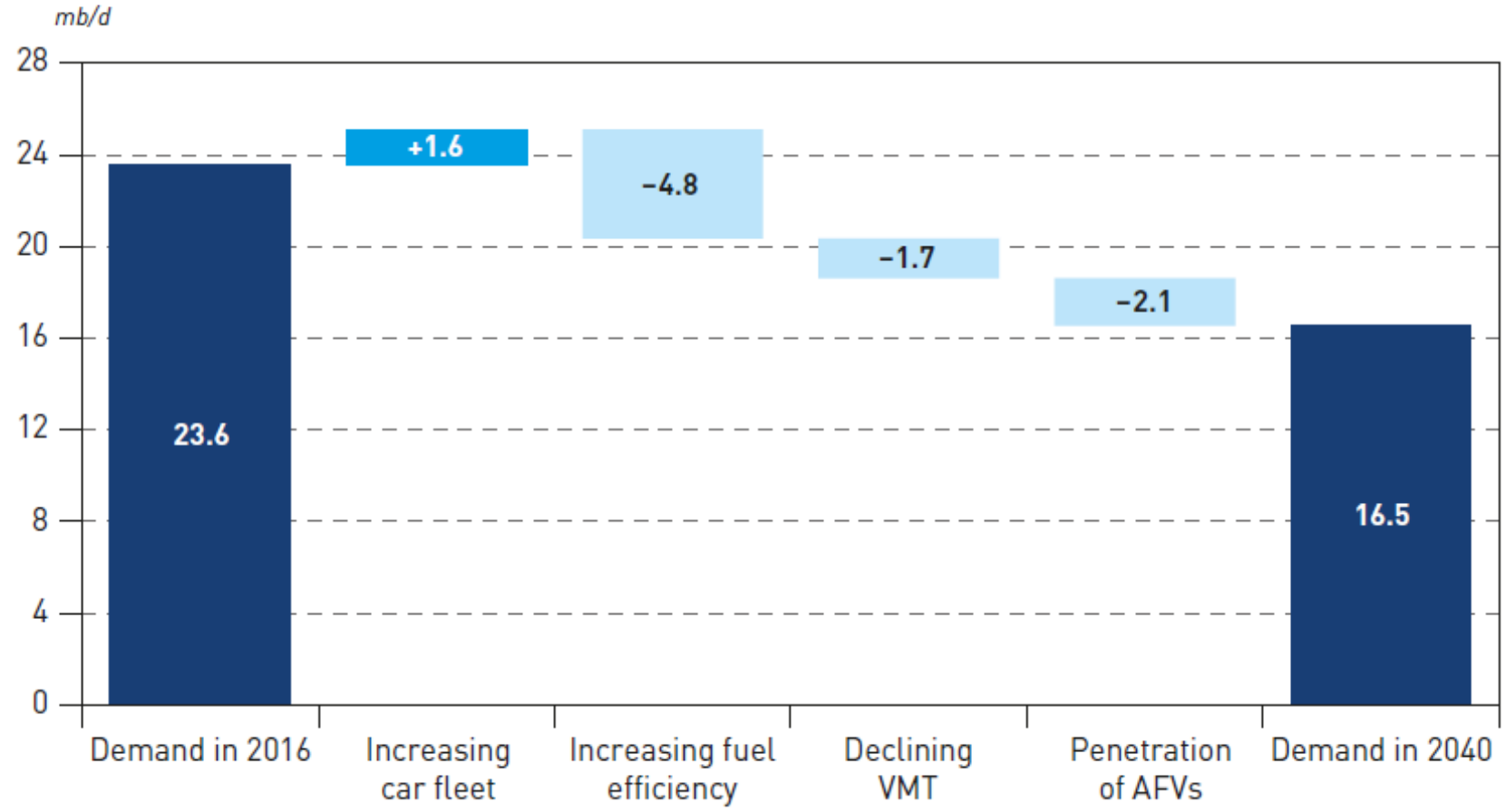


Source: https://woo.opec.org/

oil consumption

OPEC: Increasing fuel efficiency will lead to reduction in transportation oil demand in developed countries

Demand in road transportation in the OECD, 2016 and 2040

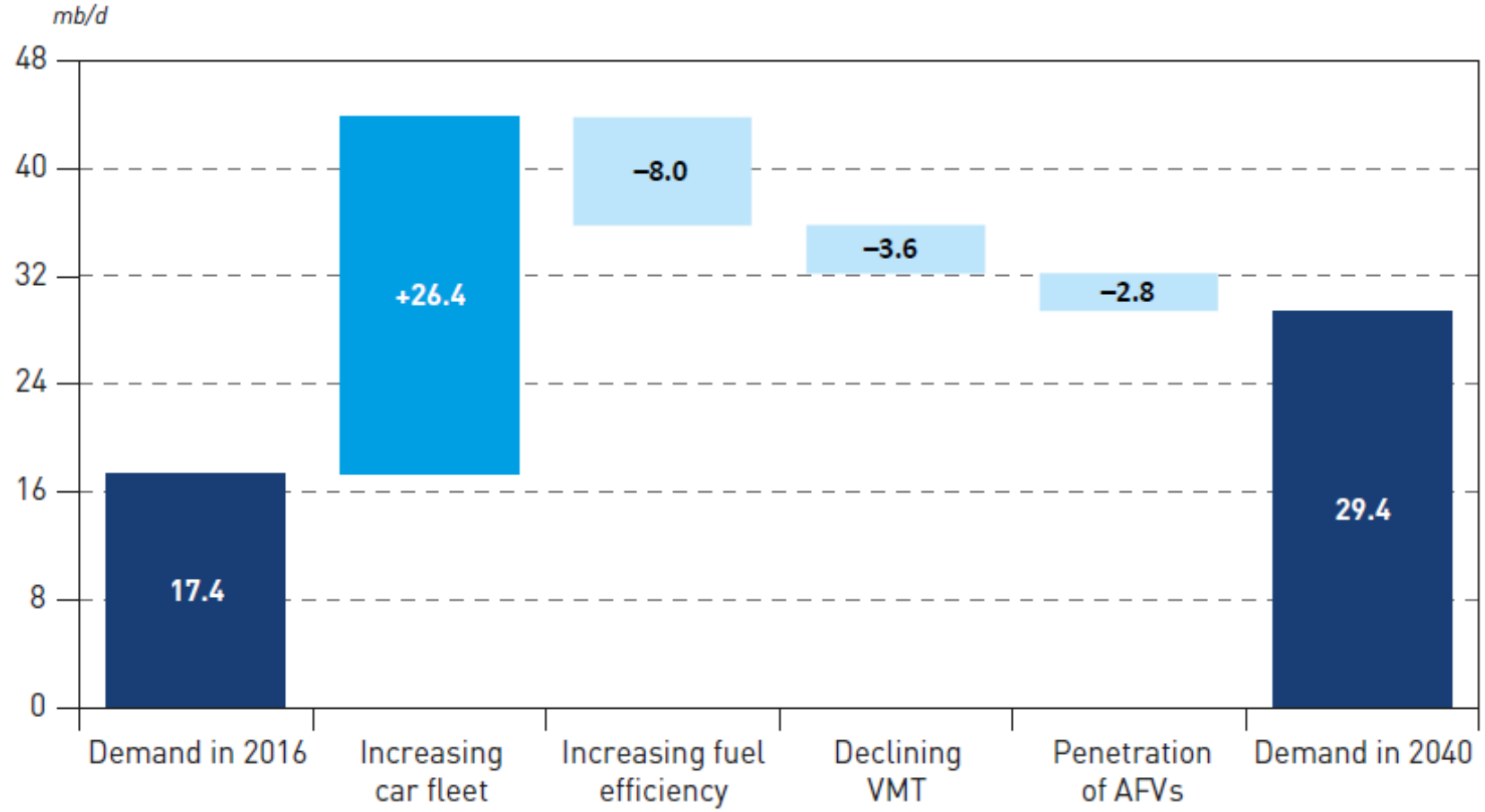


Source: https://woo.opec.org/

oil consumption

OPEC: More vehicles on the road will increase transportation oil demand in developing countries

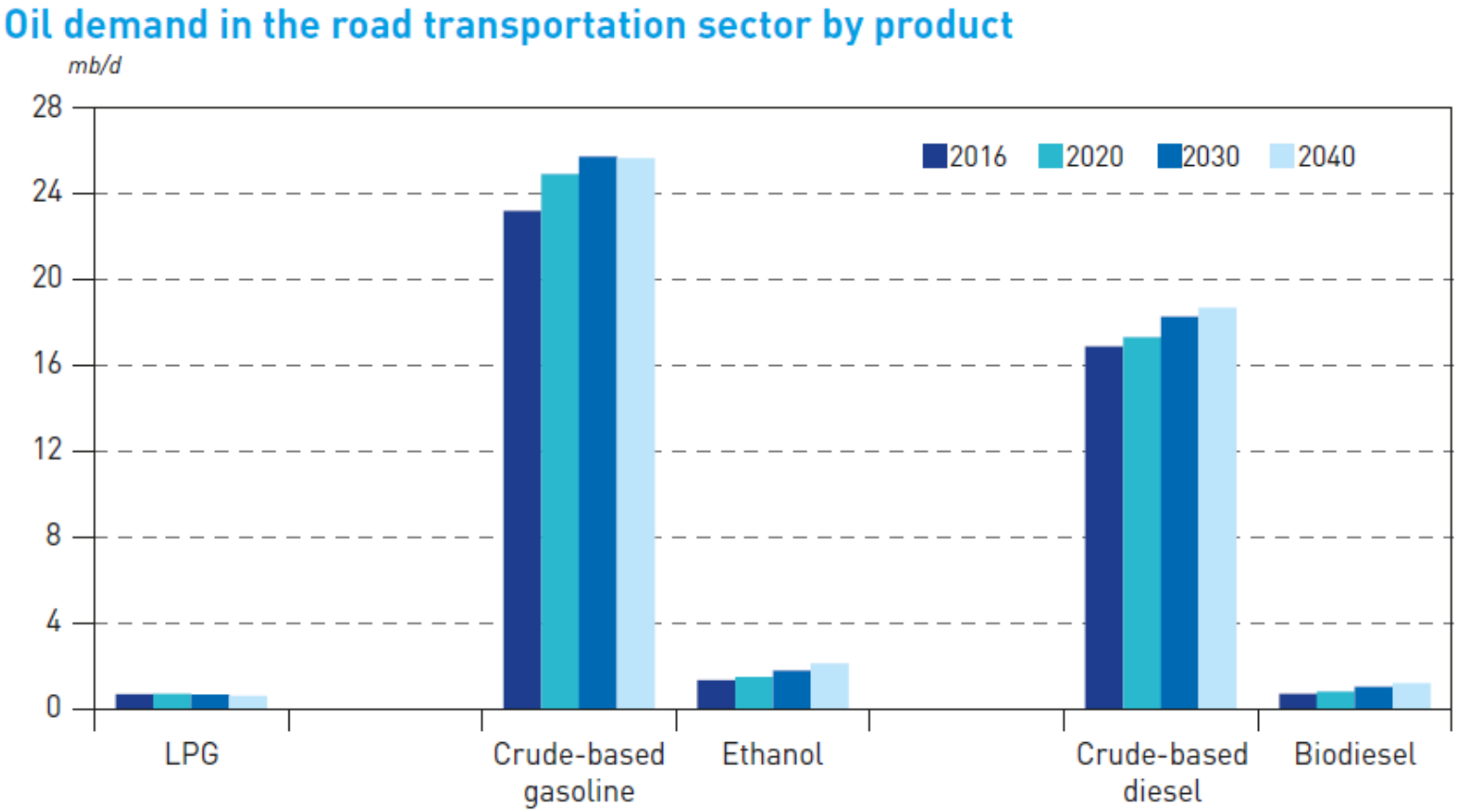
Demand in road transportation in the Developing countries, 2016 and 2040



Source: https://woo.opec.org/

oil consumption

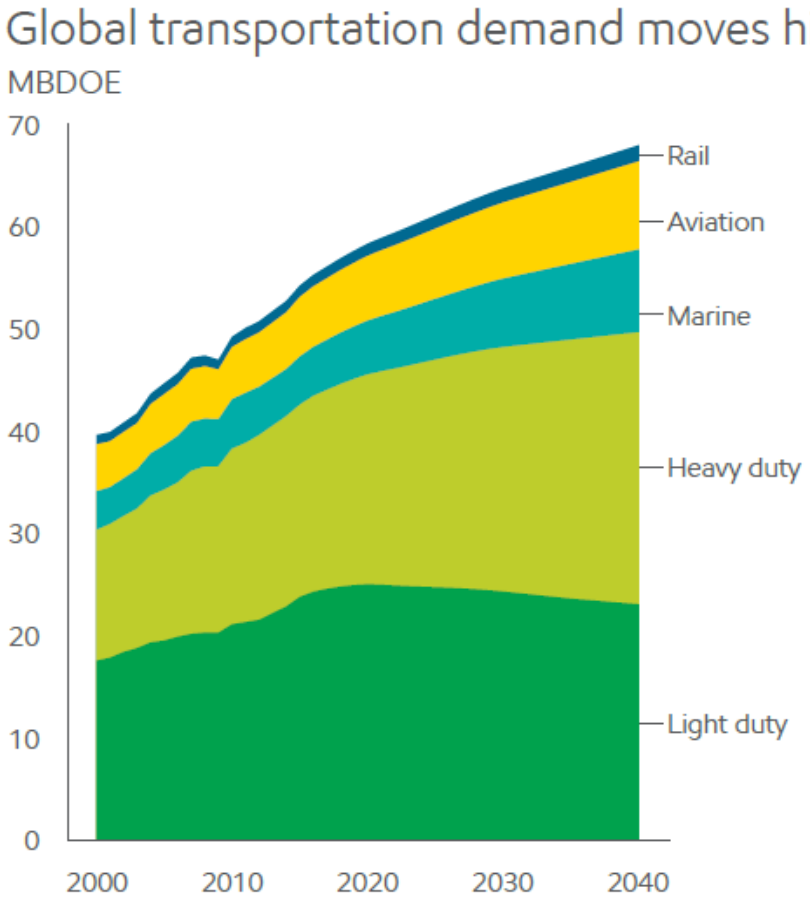
OPEC: Crude-based gasoline and diesel will continue to supply the majority of oil demand in the road transportation sector through 2040

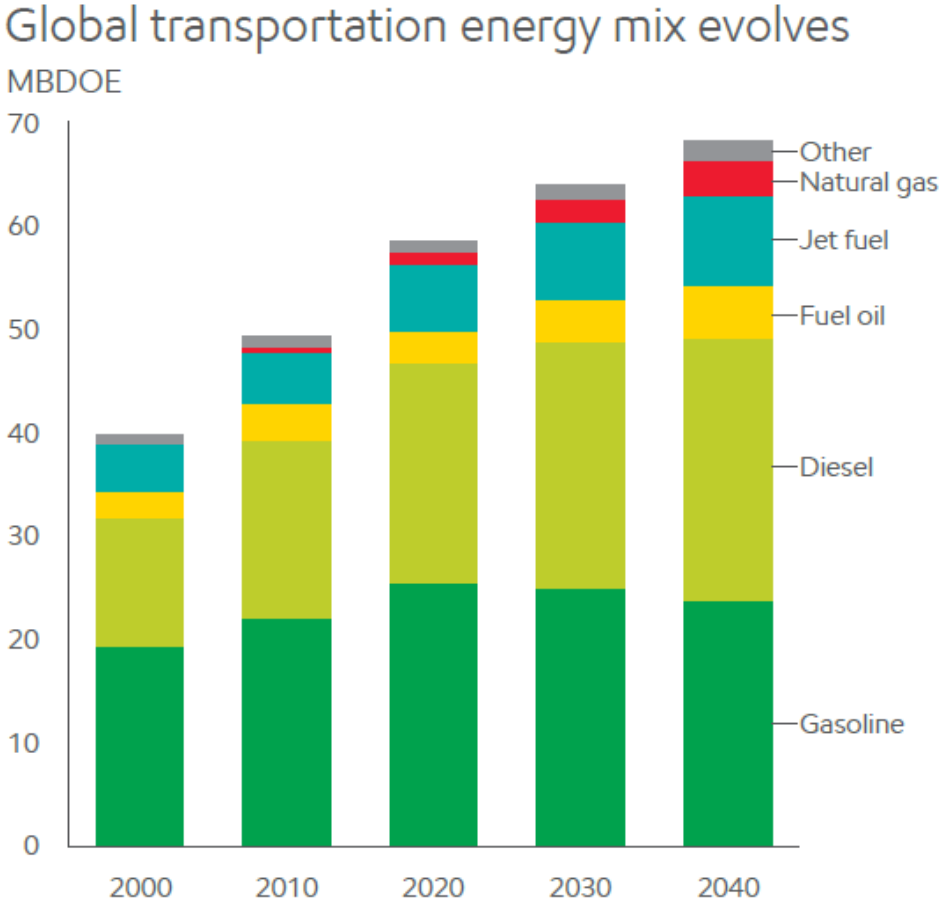


Source: https://woo.opec.org/

energy consumption

ExxonMobil: Transportation will continue to be mostly fueled by oil; LDV energy use will drop worldwide

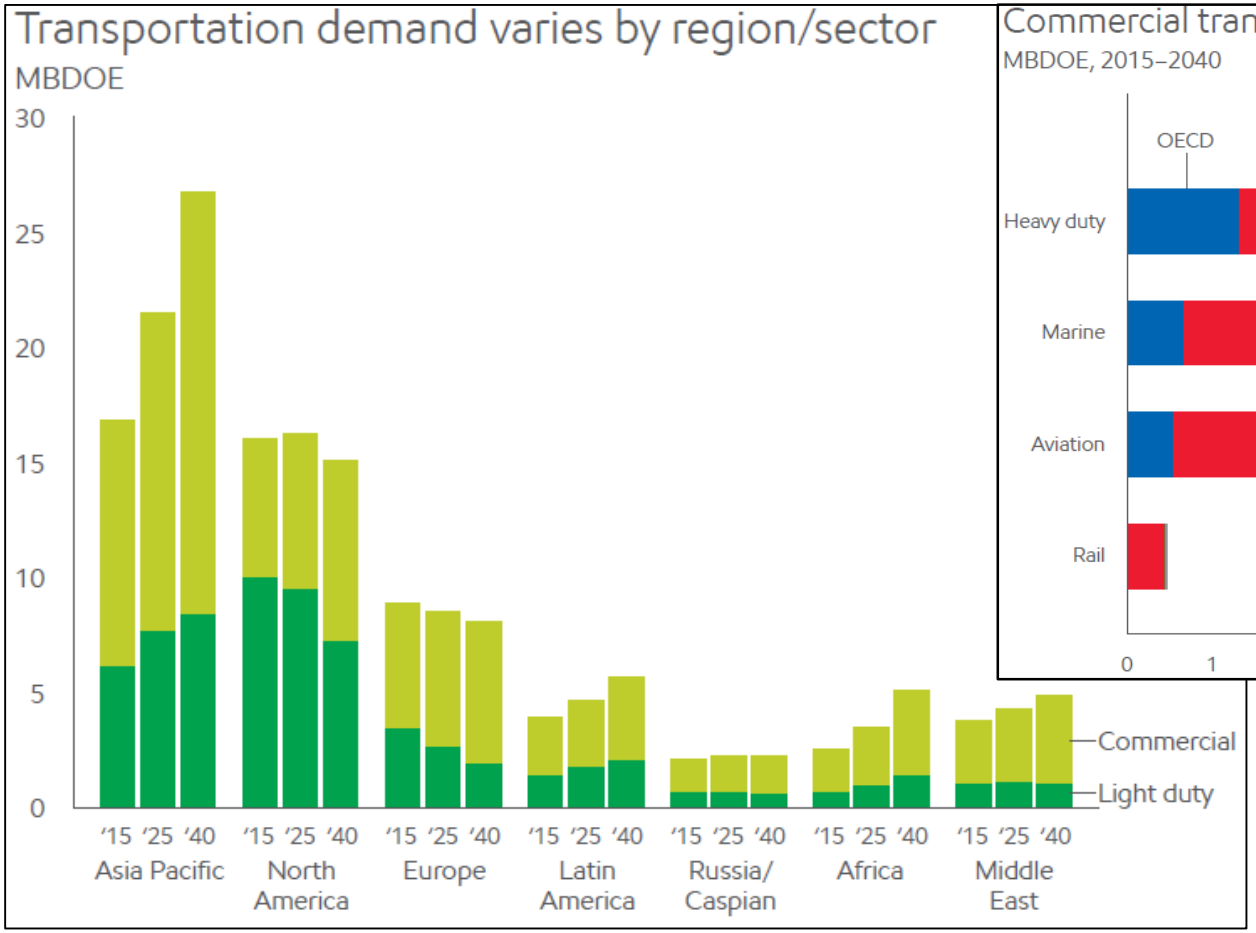


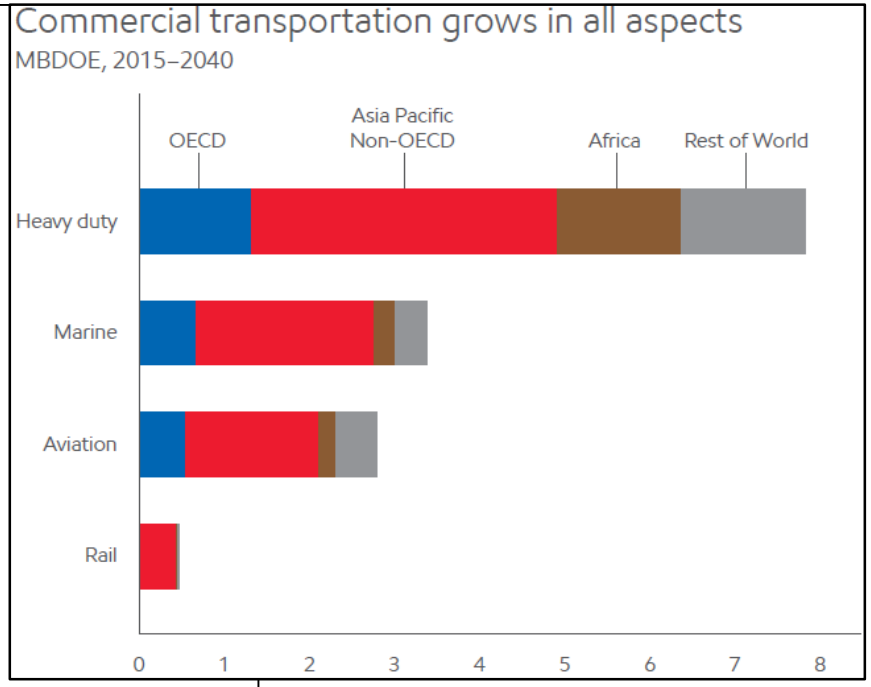


Source: http://corporate.exxonmobil.com/en/energy/energy-outlook/download-the-report/download-the-outlook-for-energy-reports

energy consumption

ExxonMobil: Commercial transportation will grow worldwide; light-duty consumption varies by country

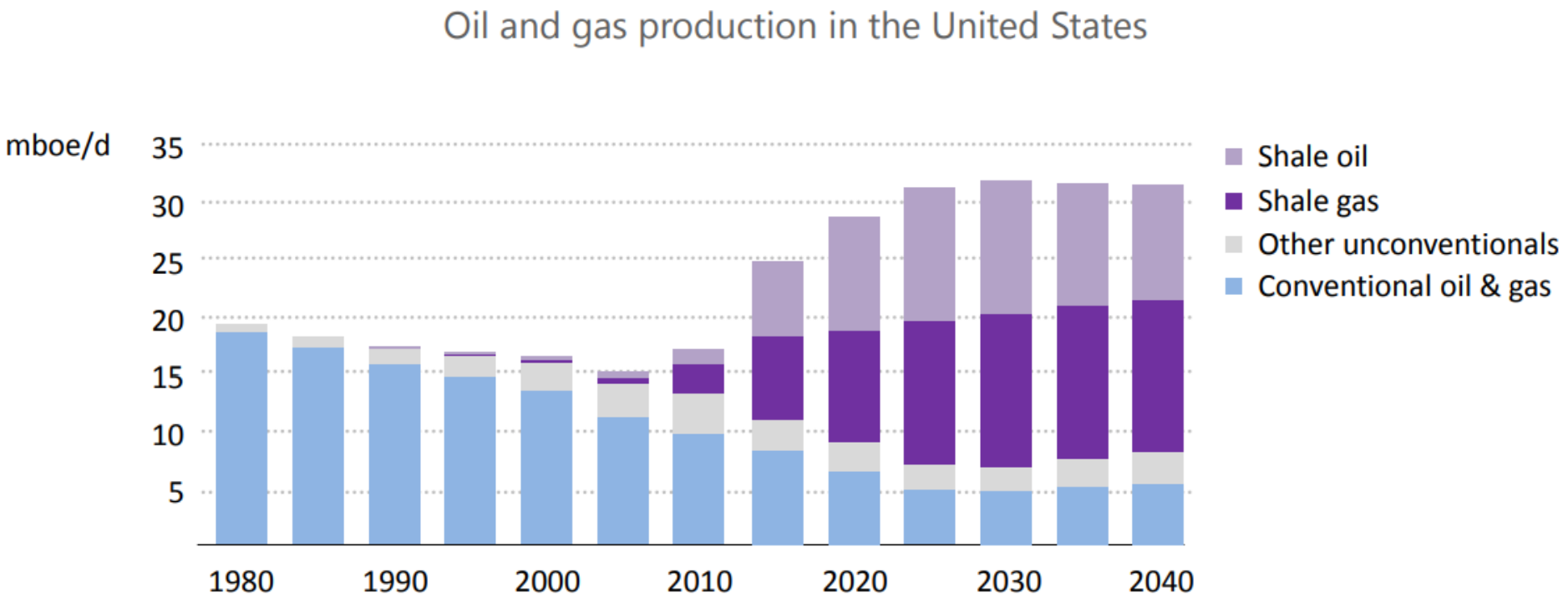




Source: http://corporate.exxonmobil.com/en/energy/energy-outlook/download-the-report/download-the-outlook-for-energy-reports

oil markets

IEA: The U.S. is poised to become the world's undisputed leader of oil and gas production

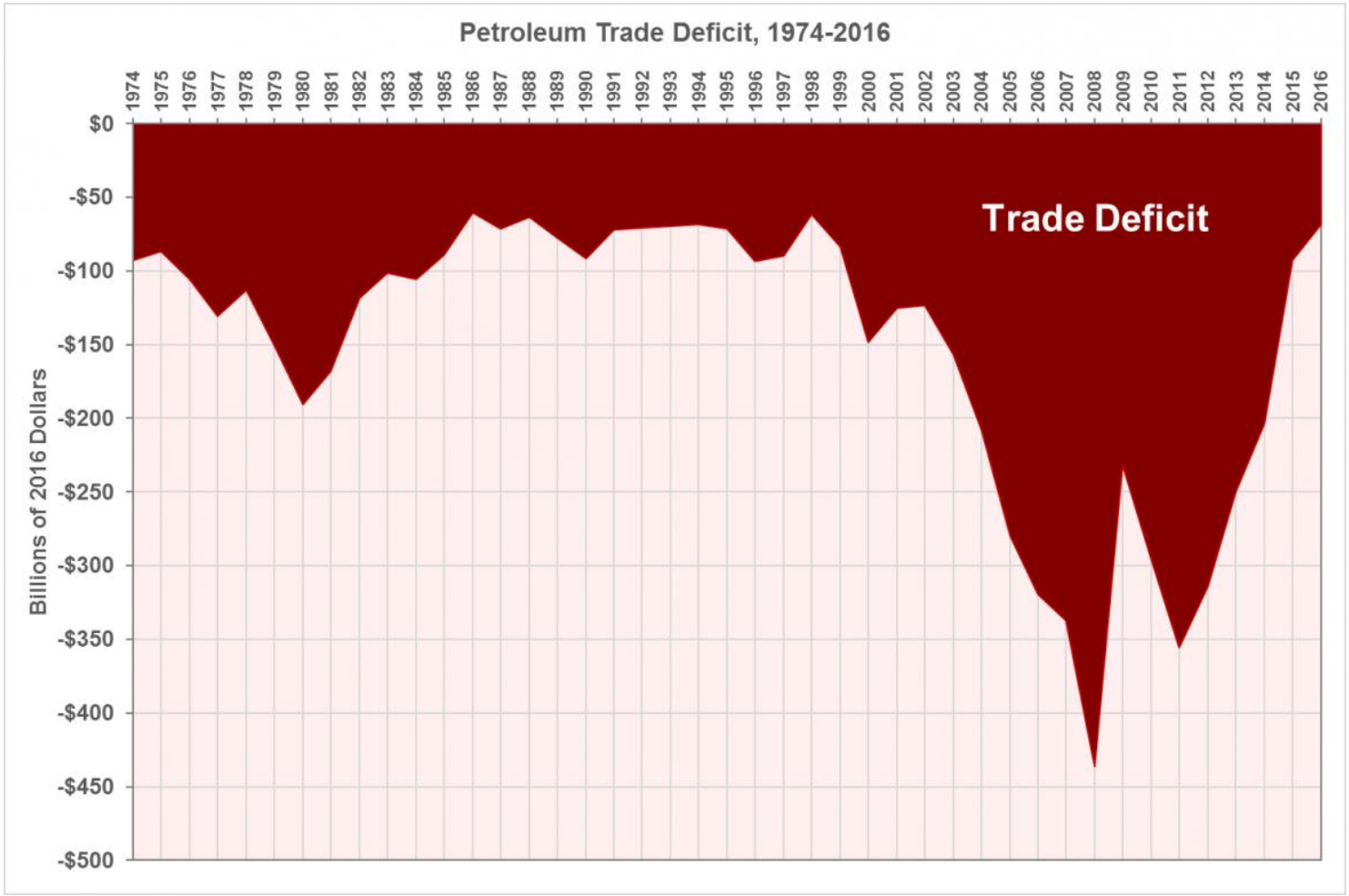


The US is already switching to become a net exporter of gas & becomes a net exporter of oil in the 2020s, helped also by the demand-side impact of fuel efficiency & fuel switching

Source: http://www.iea.org/weo2017/

oil markets

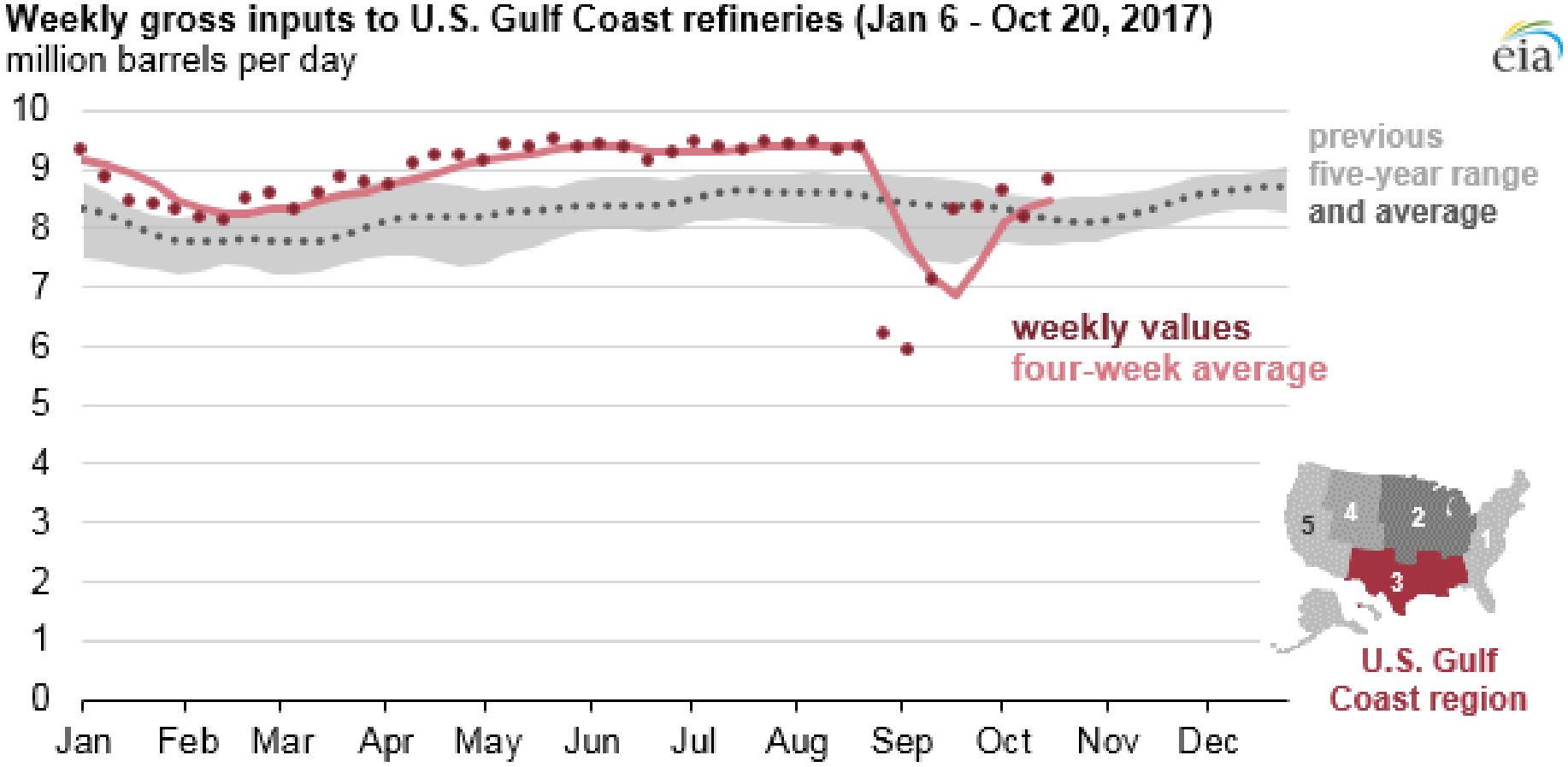
FOTW: U.S. trade deficit of petroleum in 2016 was at its lowest since 1998



Source: https://energy.gov/eere/vehicles/articles/fact-1002-november-6-2017-trade-deficit-petroleum-2016-was-its-lowest-1998

oil markets

EIA: Gulf Coast refinery inputs approached pre-Harvey levels about two months after the hurricane



Source: https://www.eia.gov/todayinenergy/detail.php?id=33492

topics

2

energy markets

automotive markets

technologies studies

environmental studies

behavior & opinion surveys

policy & business studies

qar

outline

2 automotive markets

LDV market

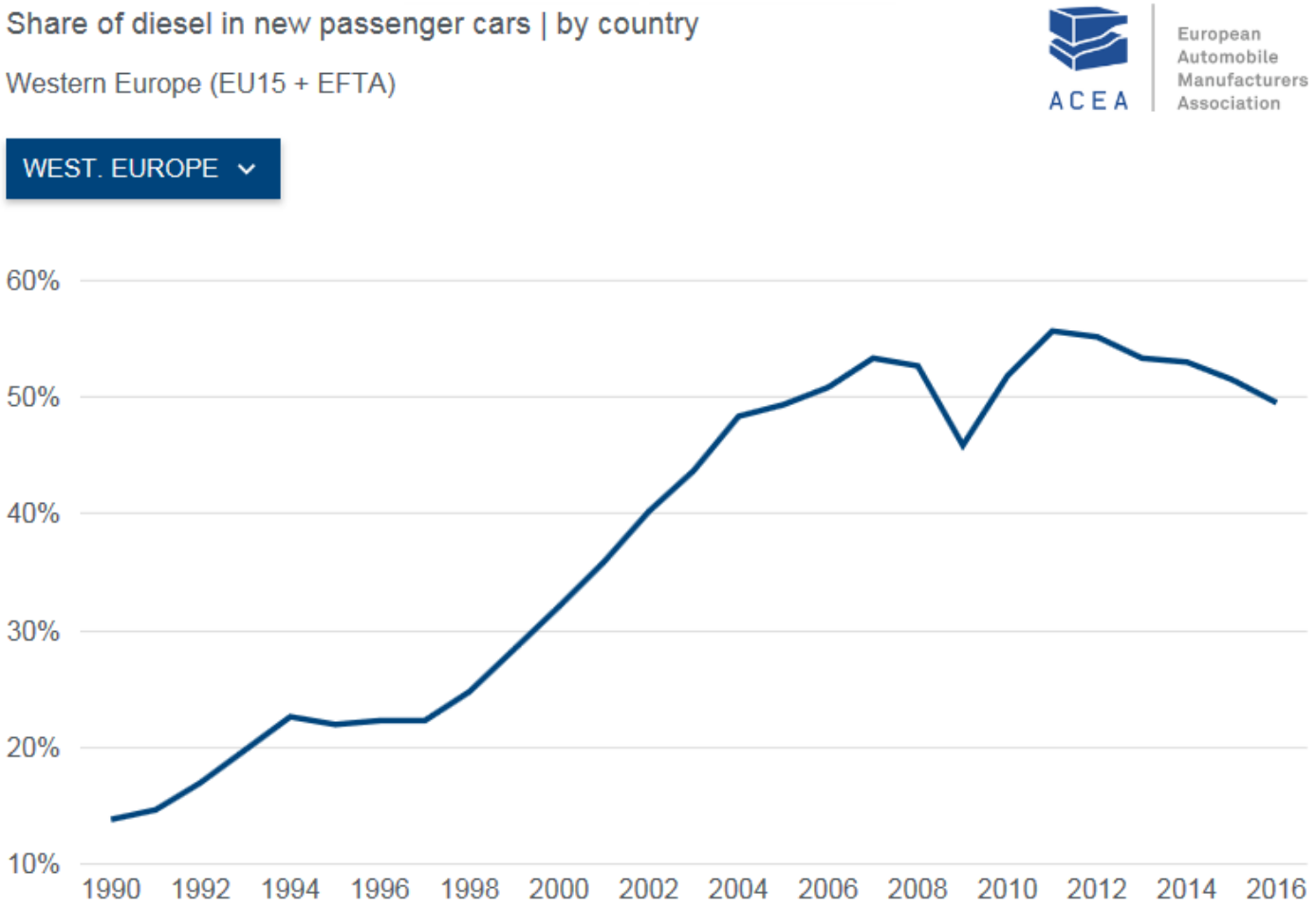
> ACEA/FOTW: Diesel share dropping in Europe, few models available in U.S.
> EV Volumes: Nearly one quarter of LDVs sold in Norway were PEVs in 2016
> FOTW: California leads U.S. in PEV registrations per capita

PEV market forecasts

> EAFO/Bloomberg/OPEC/EIA/BCG: Sales of electrified vehicles will continue to grow, but broad disagreement about specific forecasts

LDV market

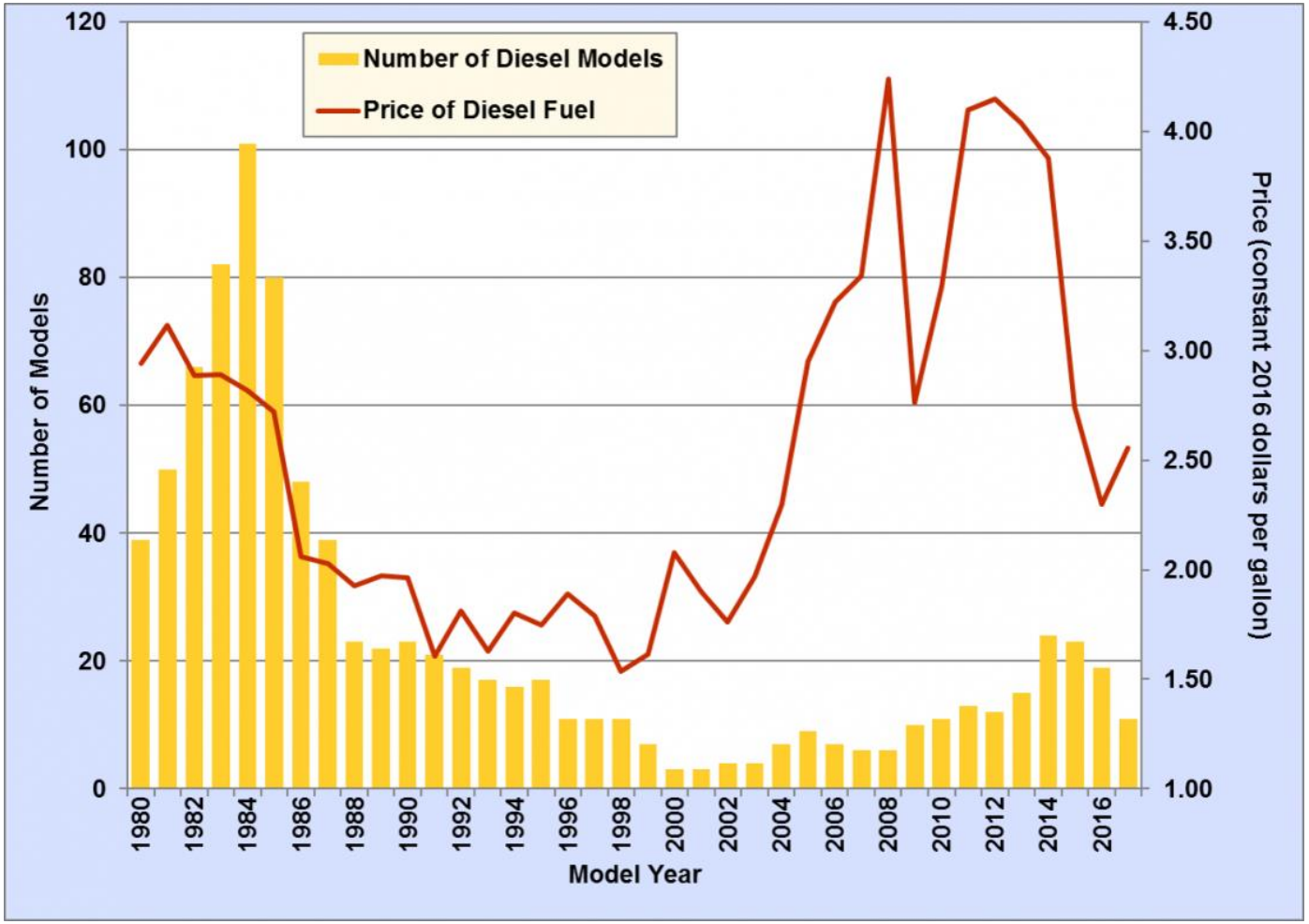
ACEA: Diesel share of LDV sales in Western Europe has dropped since 2012



Source: http://www.acea.be/statistics/tag/category/share-of-diesel-in-new-passenger-cars

LDV market

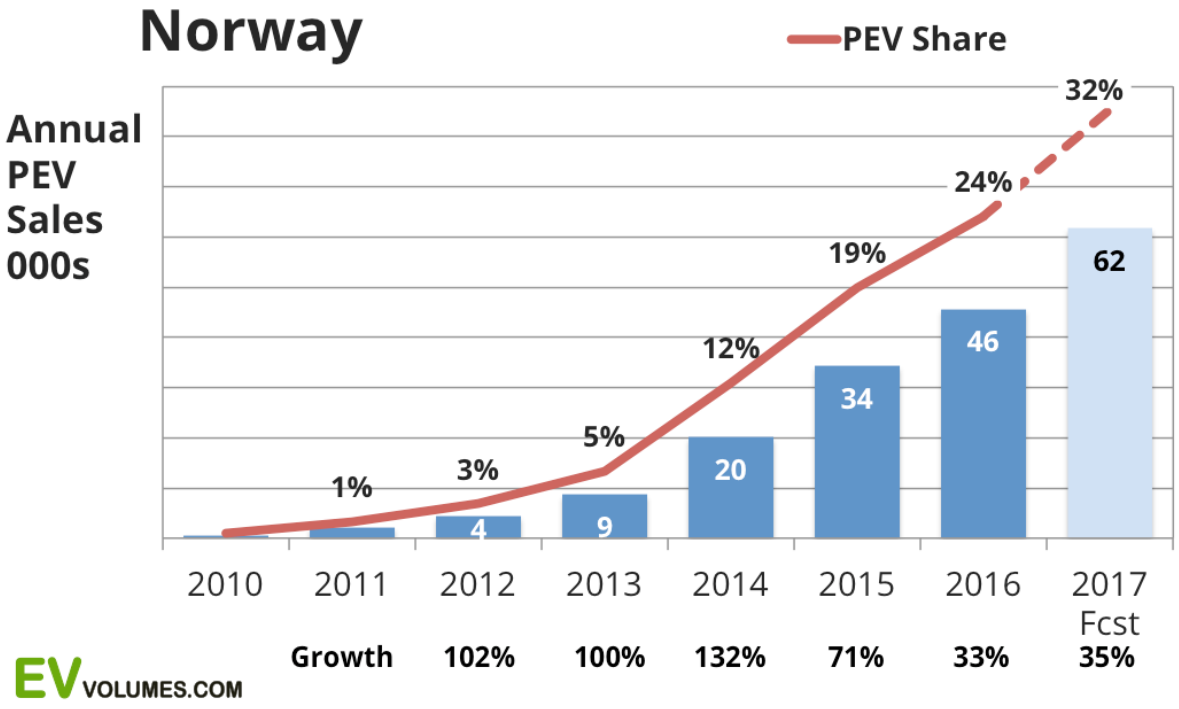
FOTW: Less than one dozen models of diesel-fueled LDV were available in MY 2017



Source: https://energy.gov/eere/vehicles/articles/fotw-1005-november-27-2017-eleven-diesel-models-sale-us-model-year-2017

PEV market

EV Volumes: Nearly one-quarter of LDVs sold in Norway were PEVs in 2016

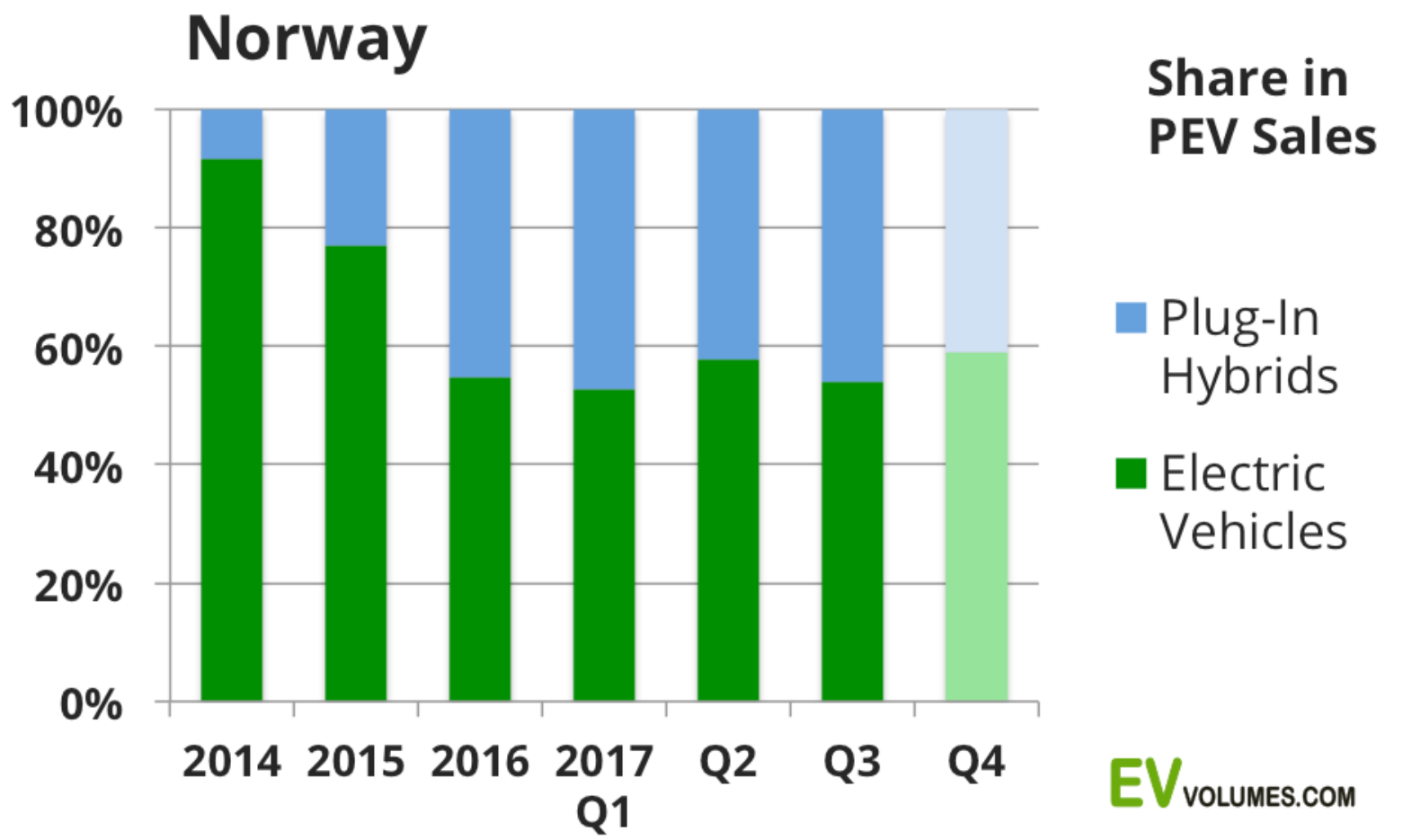


Top-20 PEV Shares		H1-2017
1	Norway	28,9%
2	Hong Kong	20,9%
3	Iceland	7,8%
4	Sweden	3,8%
5	Ukraine	2,6%
6	Belgium	2,1%
7	Switzerland	1,9%
8	Finland	1,7%
9	Luxembourg	1,6%
10	China	1,6%
11	Austria	1,6%
12	Netherlands	1,5%
13	France	1,5%
14	UK	1,4%
15	Germany	1,2%
16	Portugal	1,2%
17	New Zealand	1,2%
18	Japan	1,2%
19	USA	1,1%
20	Canada	0,7%

Source: http://www.ev-volumes.com/news/norway-plug-in-sales-q3-2017-and-ytd/

PEV market

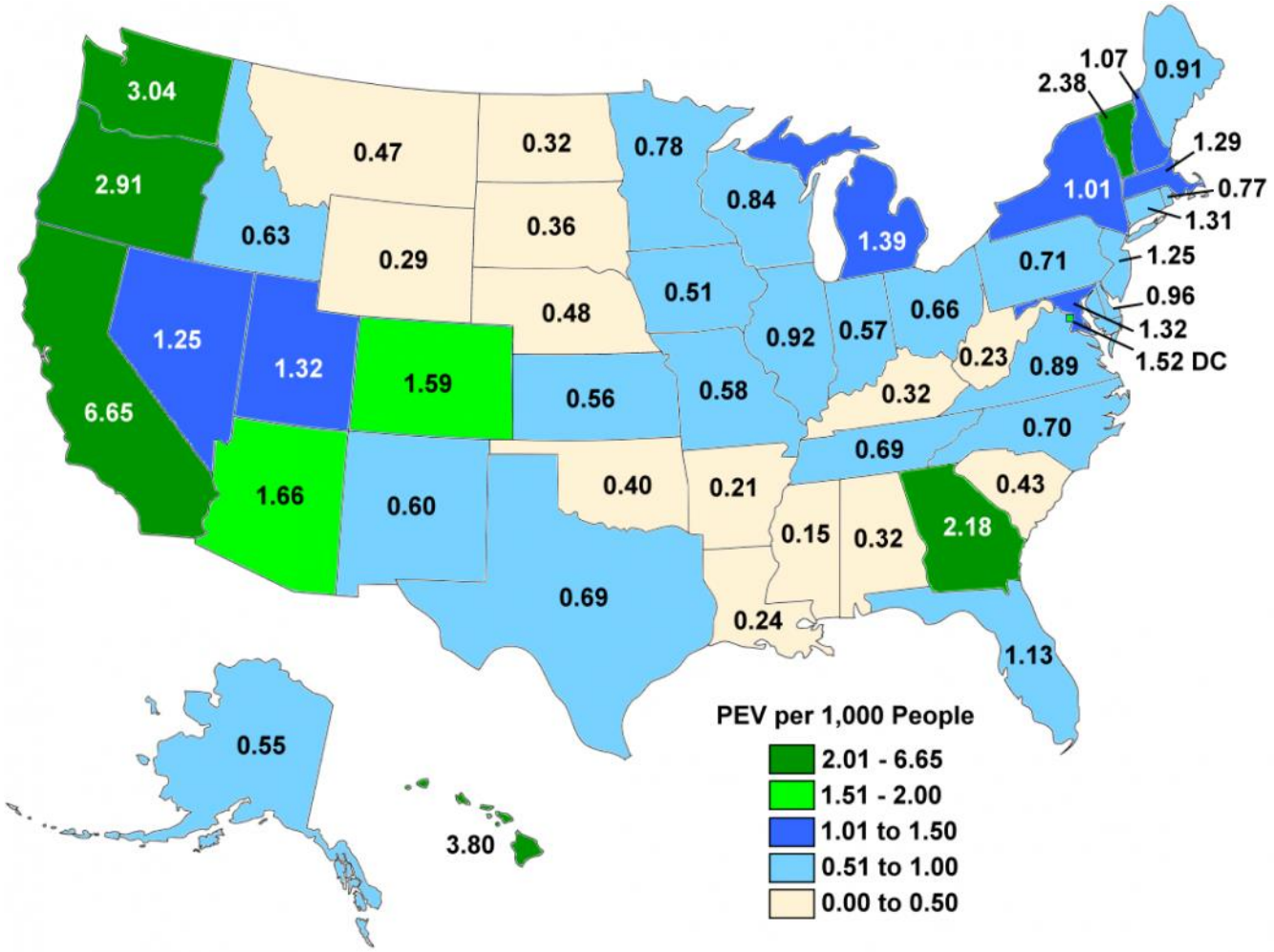
EV Volumes: As Norwegian PEV market moves beyond early adopters, PHEVs have gained sales share



Source: http://www.ev-volumes.com/news/norway-plug-in-sales-q3-2017-and-ytd/

PEV market

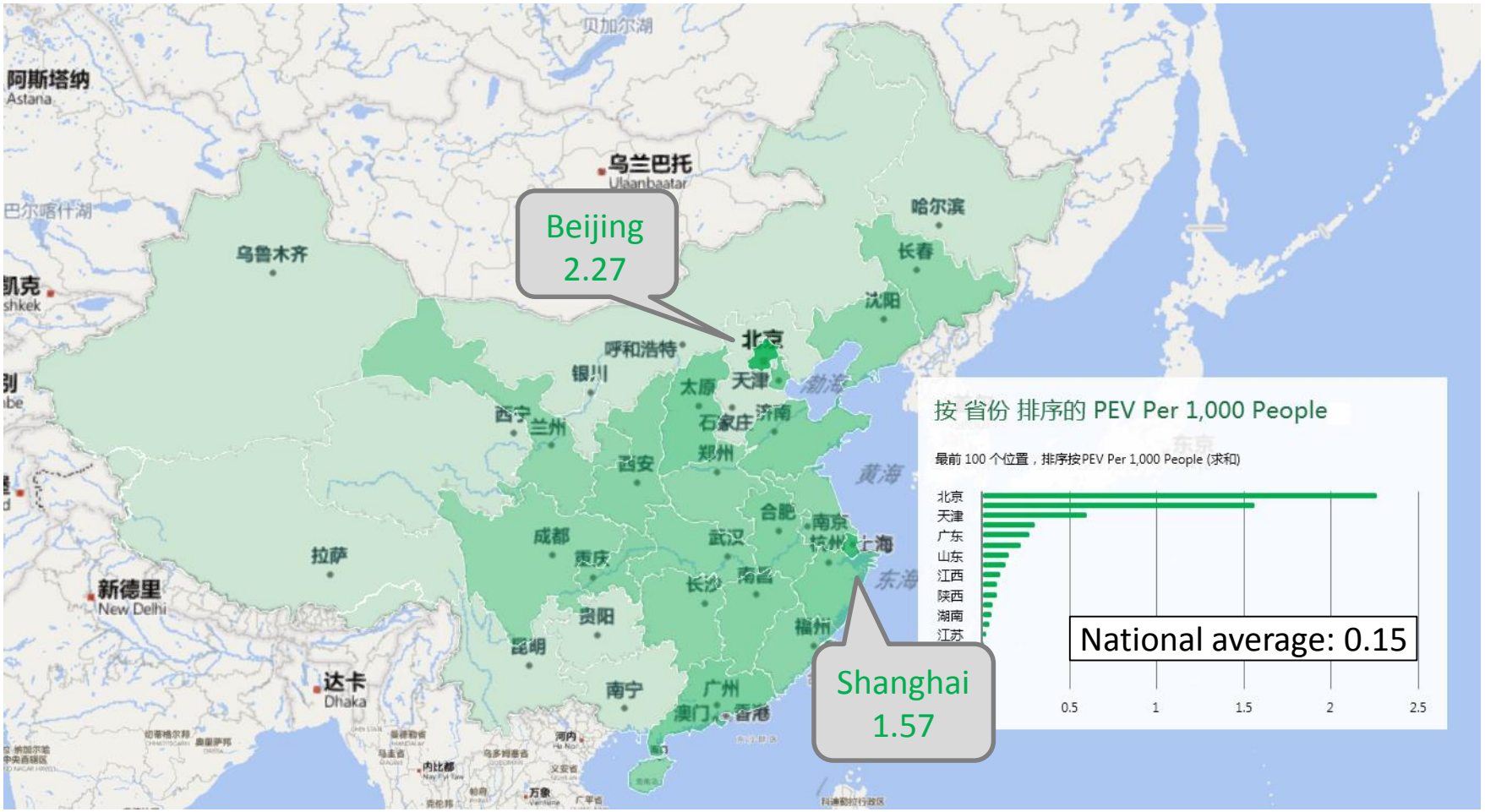
FOTW: California had the highest per-capita concentration of PEVs in the United States in 2016



Source: https://energy.gov/eere/vehicles/articles/fotw-1004-november-20-2017-california-had-highest-concentration-plug-vehicles

PEV market

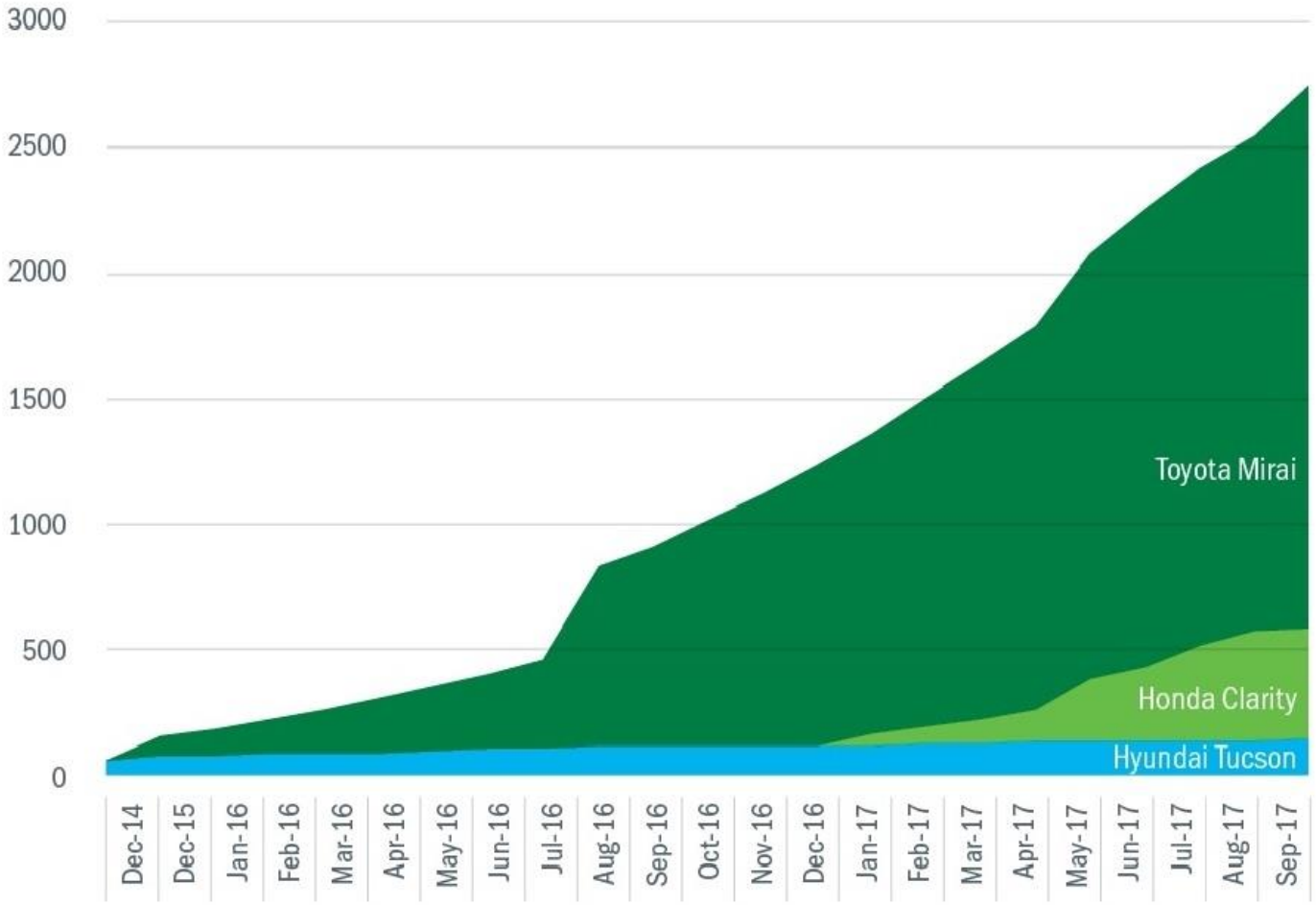
ANL: Beijing and Shanghai would both be in top ten U.S. states with over 1.5 PEV / 1000 people



Source: Y. Zhou, ANL

FCV market

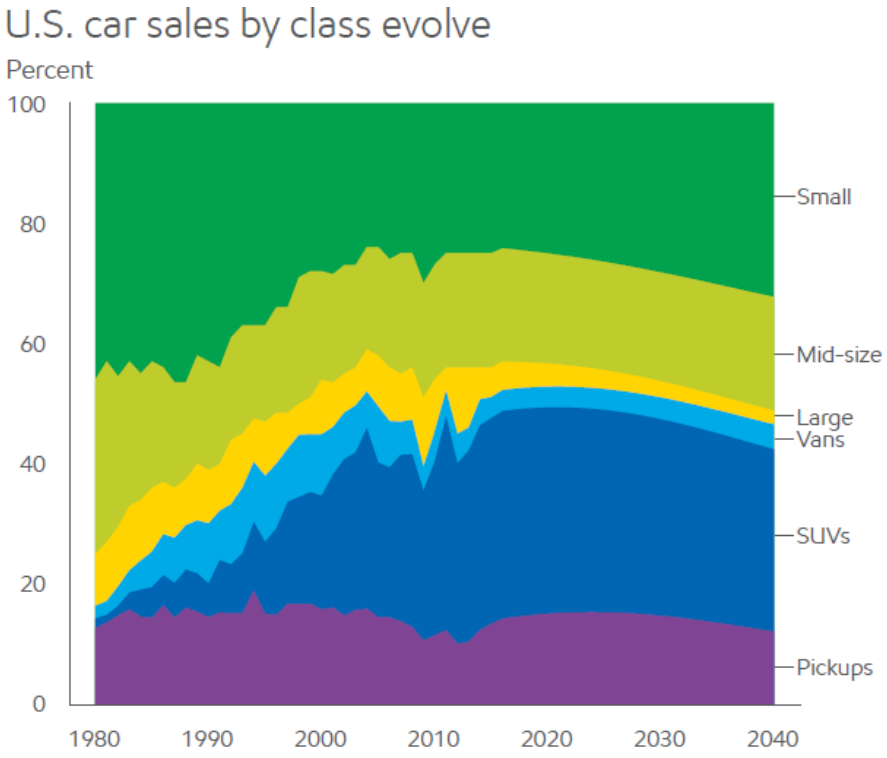
FCTO: Cumulative U.S. sales of fuel cell vehicles have reached nearly 3,000

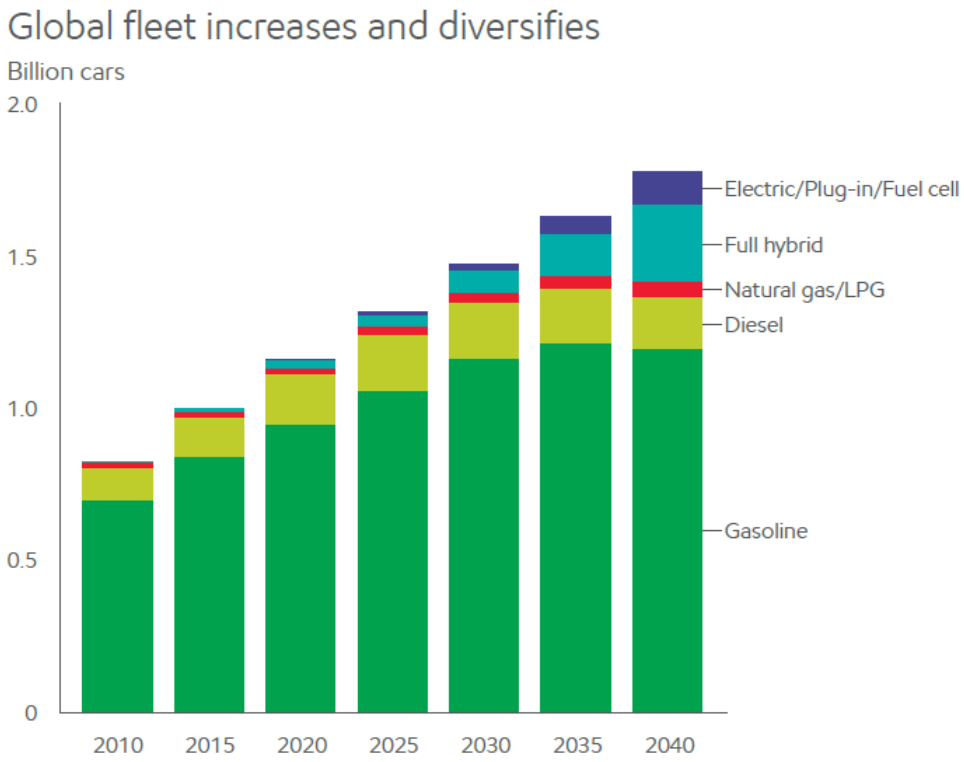


Source: https://energy.gov/eere/fuelcells/fact-month-17-01-november-15-cumulative-us-sales-fuel-cell-vehicles-totaled-2748-june

LDV market forecasts

ExxonMobil: U.S. LDVs will trend toward smaller vehicles; gasoline ICE fleet will peak worldwide by 2035

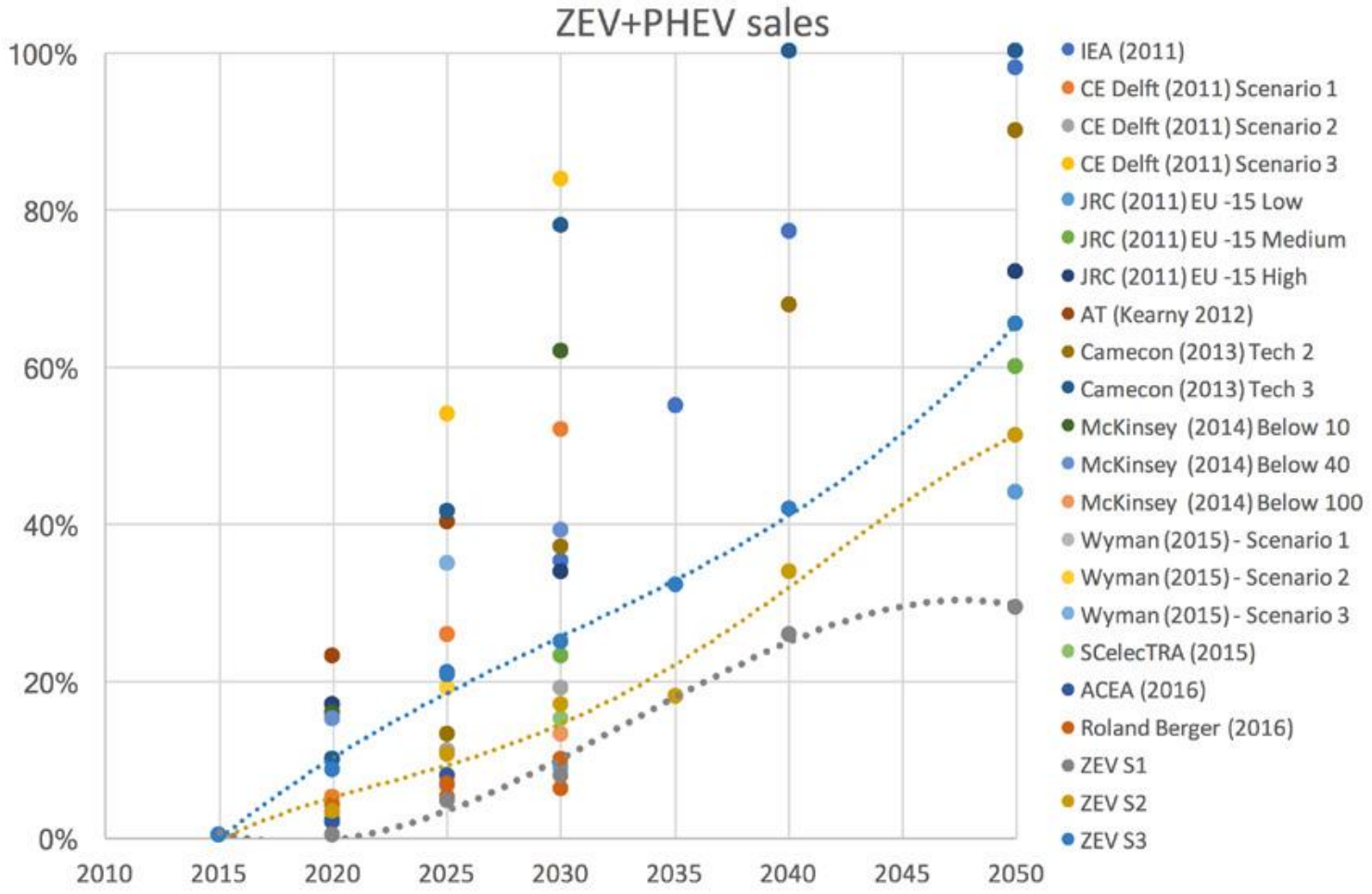




Source: http://corporate.exxonmobil.com/en/energy/energy-outlook/download-the-report/download-the-outlook-for-energy-reports

PEV market forecasts

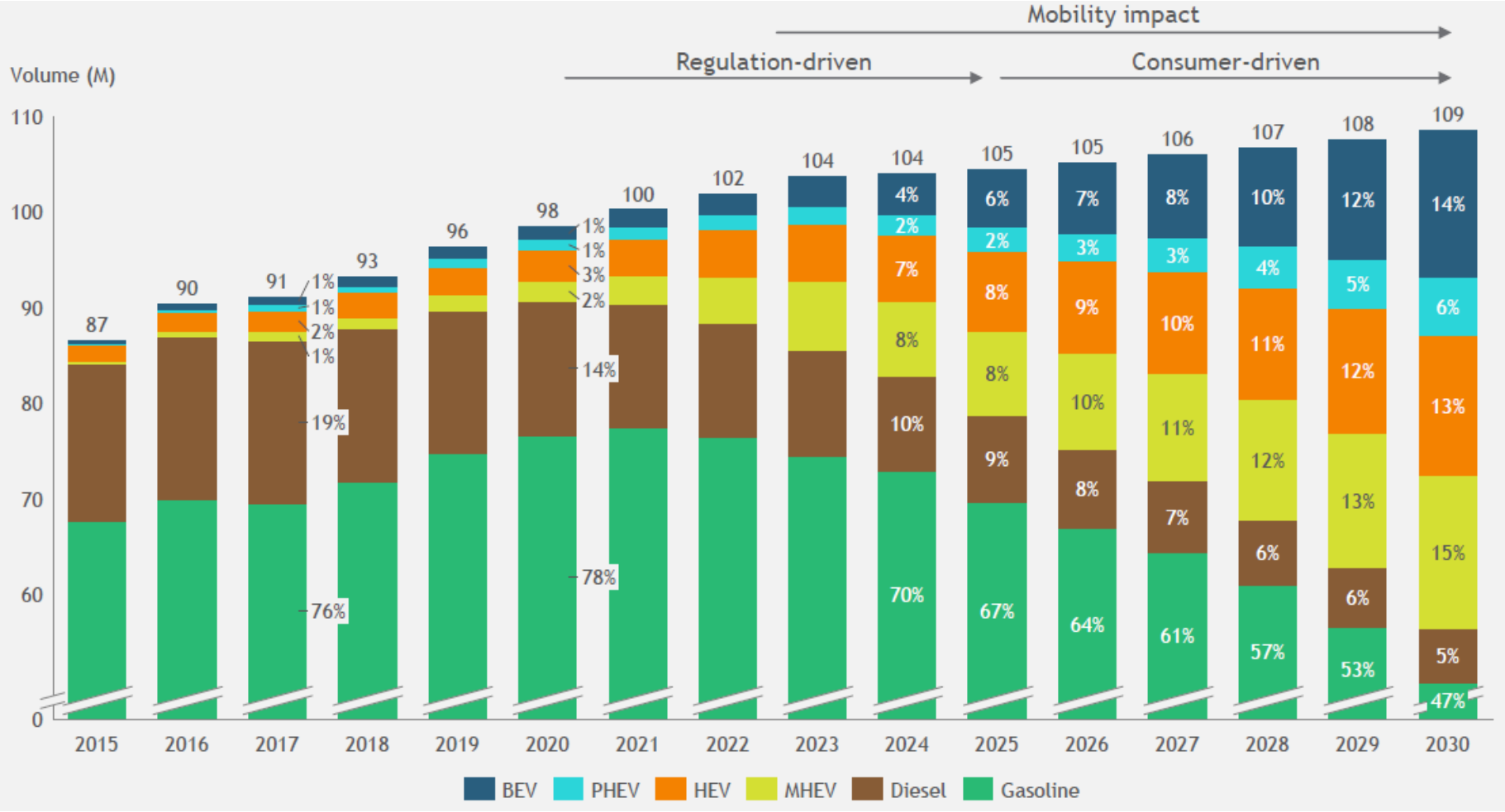
EAFO: Forecasts for (EU) PEV sales show trend toward increased share but broad disagreement in specifics



Source: http://avere.org/EAFOZEVSTUDY.pdf

PEV market forecasts

BCG: PEVs will have 20% of the worldwide market, hybrids (HEV/MHEV) another 28% by 2030



Source: https://www.bcg.com/d/press/2november2017-electrified-vehicles-take-half-of-global-auto-market-175464

topics

energy markets

automotive markets

3 technologies studies

environmental studies

behavior & opinion surveys

policy & business studies

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outline

3 technologies studies

R&D

> ANL: VTO R&D program success can reduce petroleum consumption by 3 mmbpd and reduce consumer fuel costs by $200B/year by 2050

fuel economy

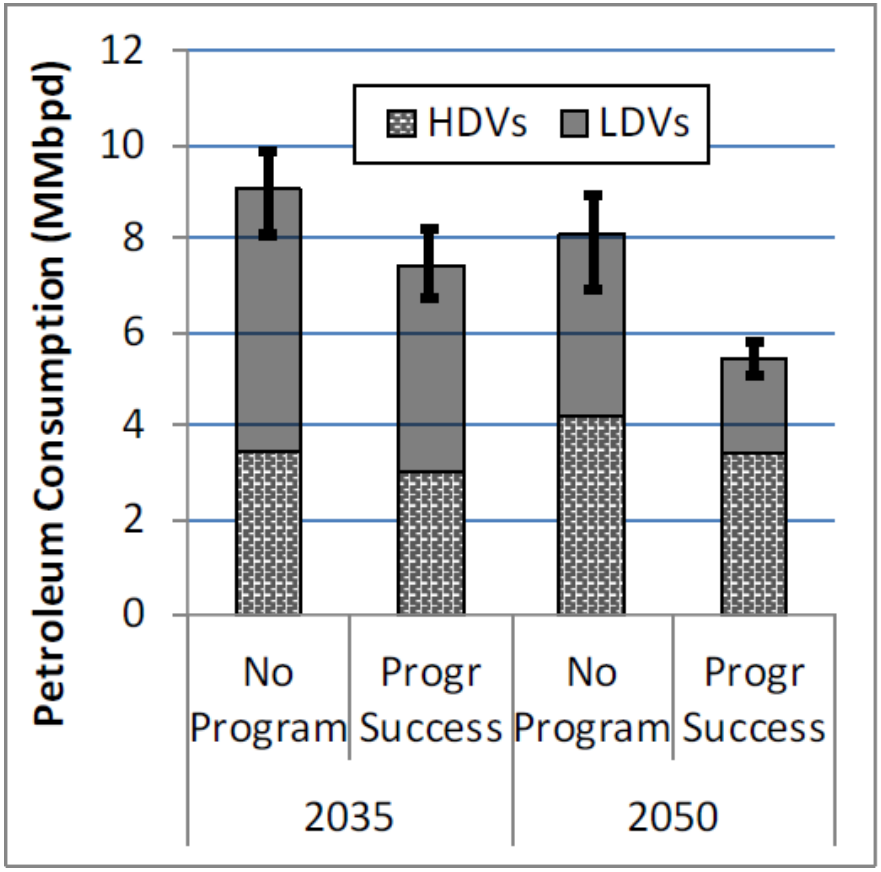
> ORNL/MIT: ICEV, HEV, and BEV have different fuel economy trends for different driving behaviors

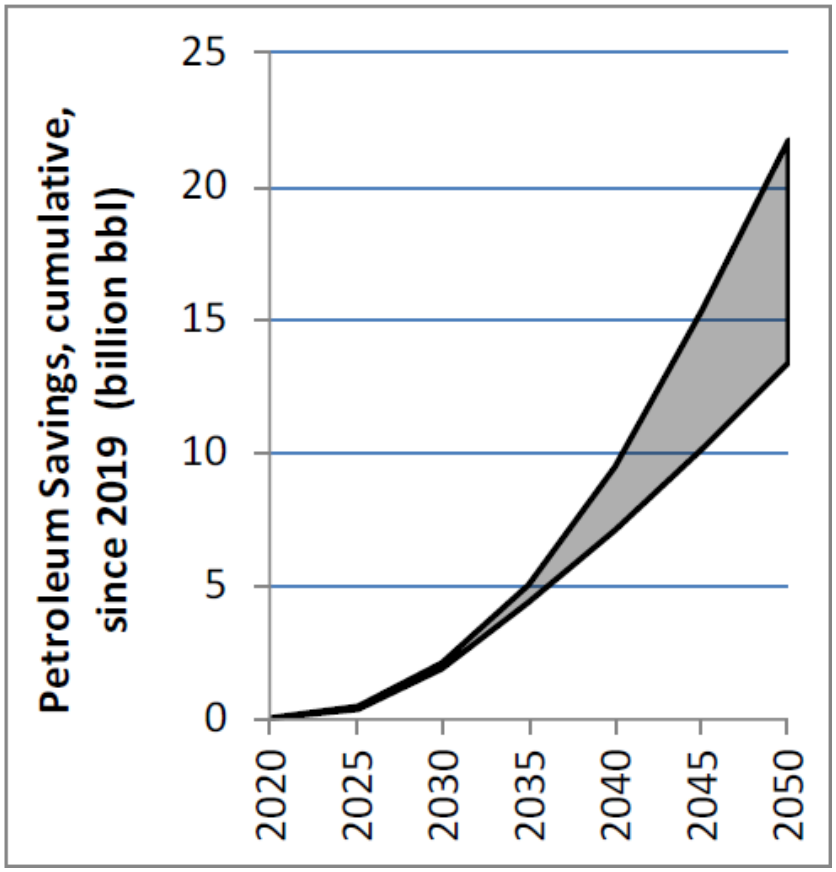
vehicle design

> McKinsey: OEMs have different strategies for vehicle design for PEVs
> EV Volumes: NMC now most common battery chemistry
> DOE: Accounting for extreme fast charging can change vehicle design

VTO R&D

ANL: VTO R&D program success can reduce petroleum consumption by over 3 million barrels per day in 2050

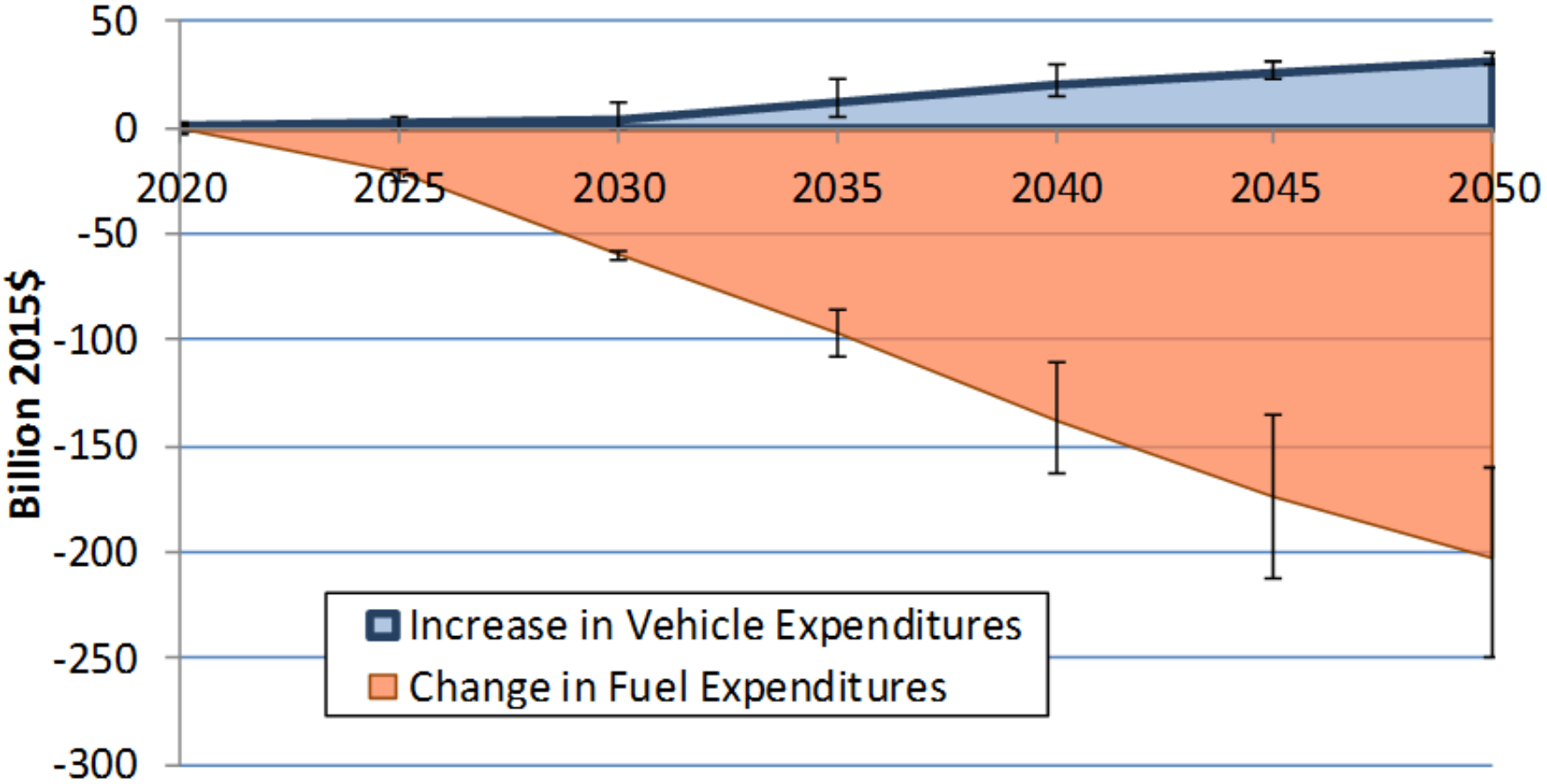




Source: https://www.osti.gov/scitech/biblio/1410412-vehicle-technologies-fuel-cell-technologies-office-research-development-programs-prospective-benefits-assessment-report-fiscal-year

VTO R&D

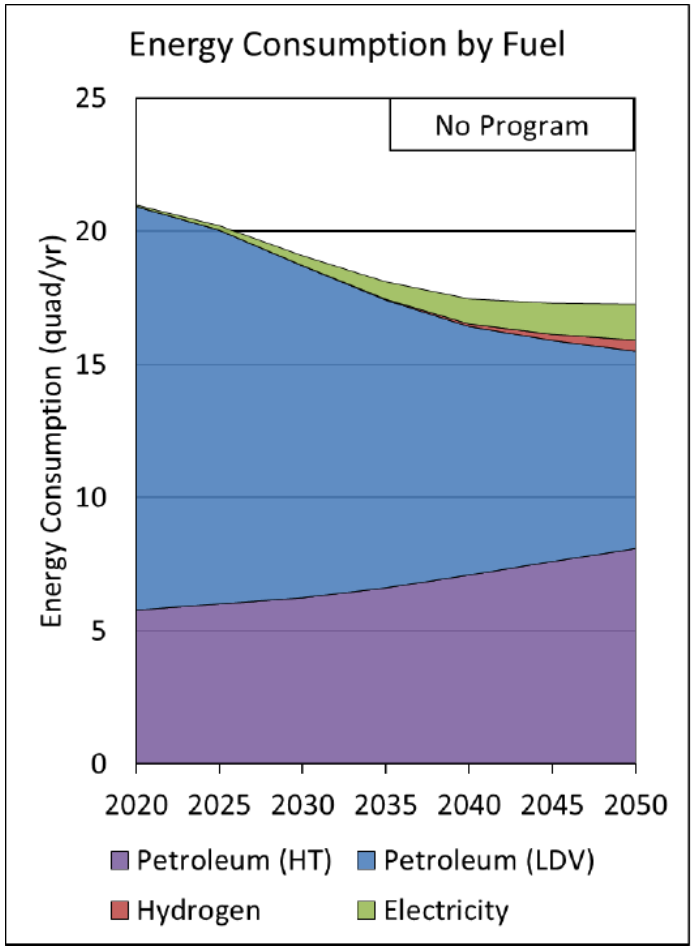
ANL: Successful VTO R&D can reduce consumer fuel costs by over $200 billion per year by 2050

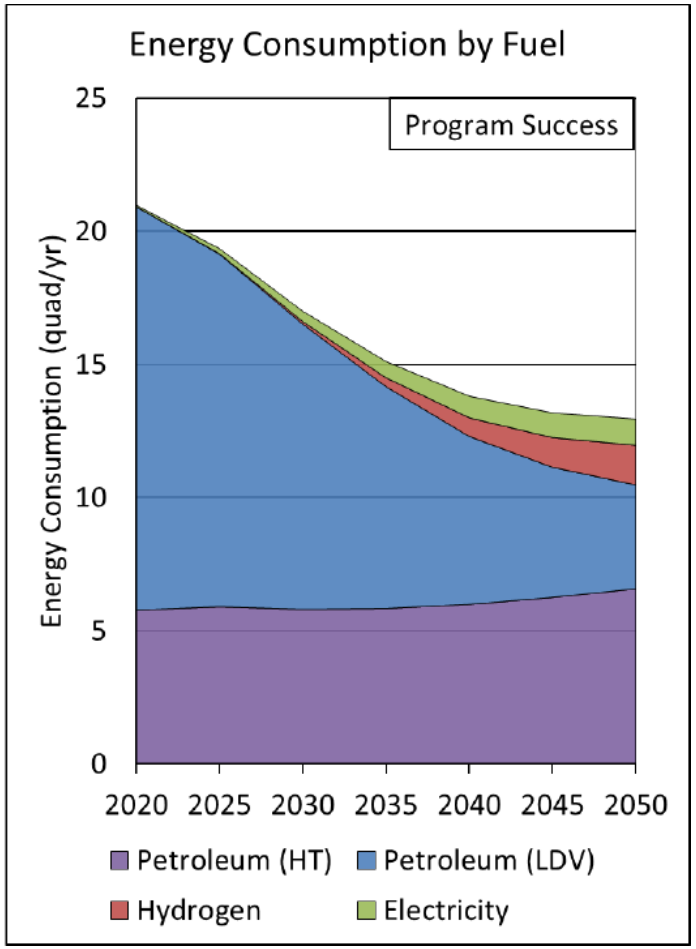


Source: https://www.osti.gov/scitech/biblio/1410412-vehicle-technologies-fuel-cell-technologies-office-research-development-programs-prospective-benefits-assessment-report-fiscal-year

VTO R&D

ANL: Heavy trucks will make up an increasing share of total energy usage through 2050

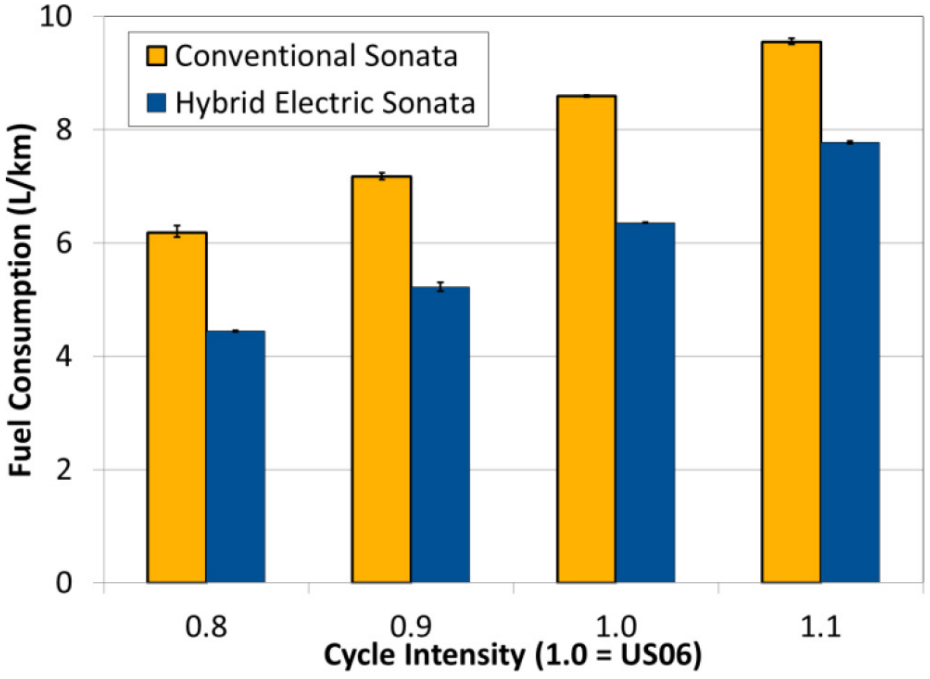


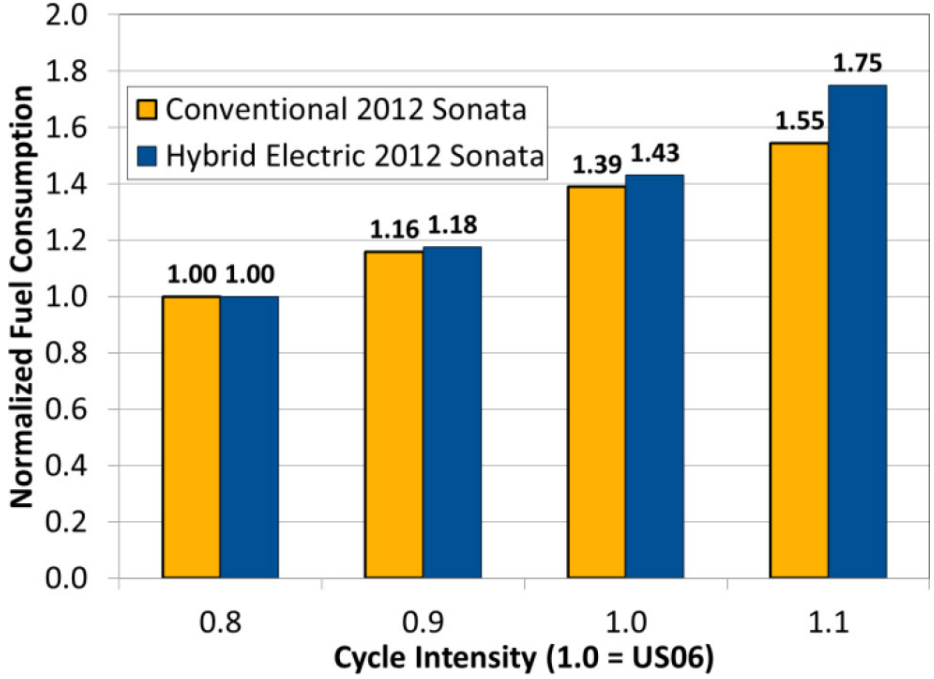


Source: https://www.osti.gov/scitech/biblio/1410412-vehicle-technologies-fuel-cell-technologies-office-research-development-programs-prospective-benefits-assessment-report-fiscal-year

fuel economy

ORNL: Fuel consumption for HEVs is lower than for ICEVs, but is more sensitive to aggressive driving

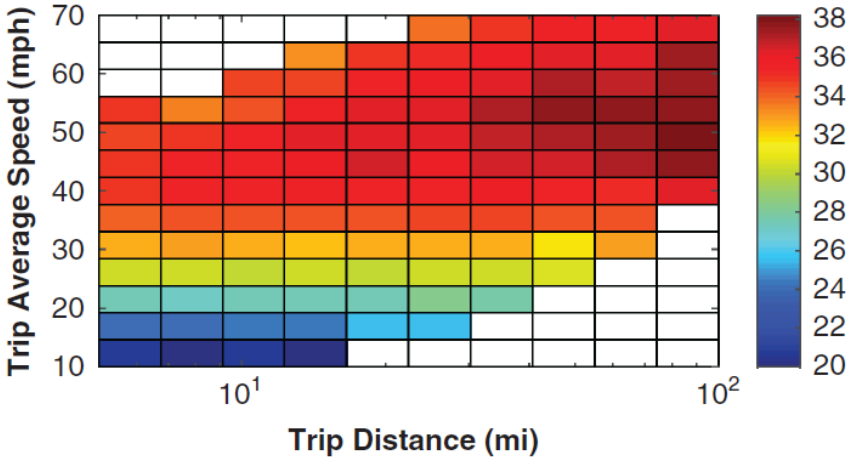




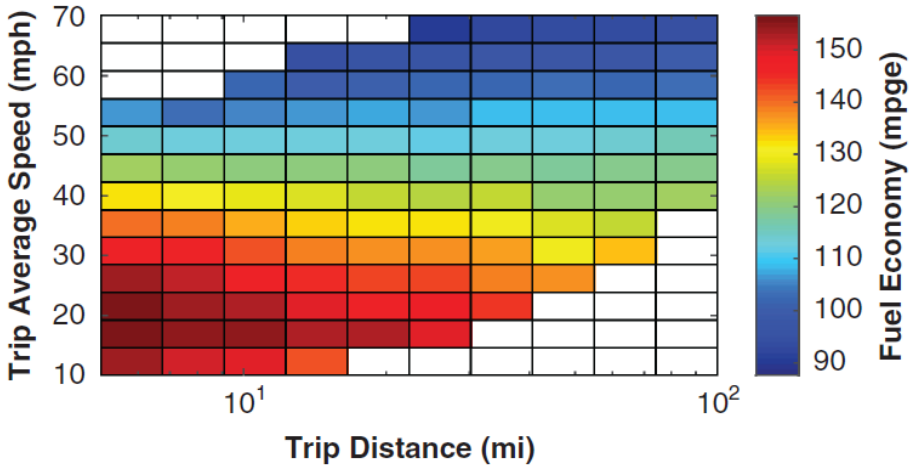
Source: https://www.afdc.energy.gov/uploads/publication/fuel_consumption_sensitivity_style.pdf

fuel economy

MIT: BEVs modeled to have better fuel economy at low average speeds while ICEVs better at highway speeds



ICE fuel economy (modeled)

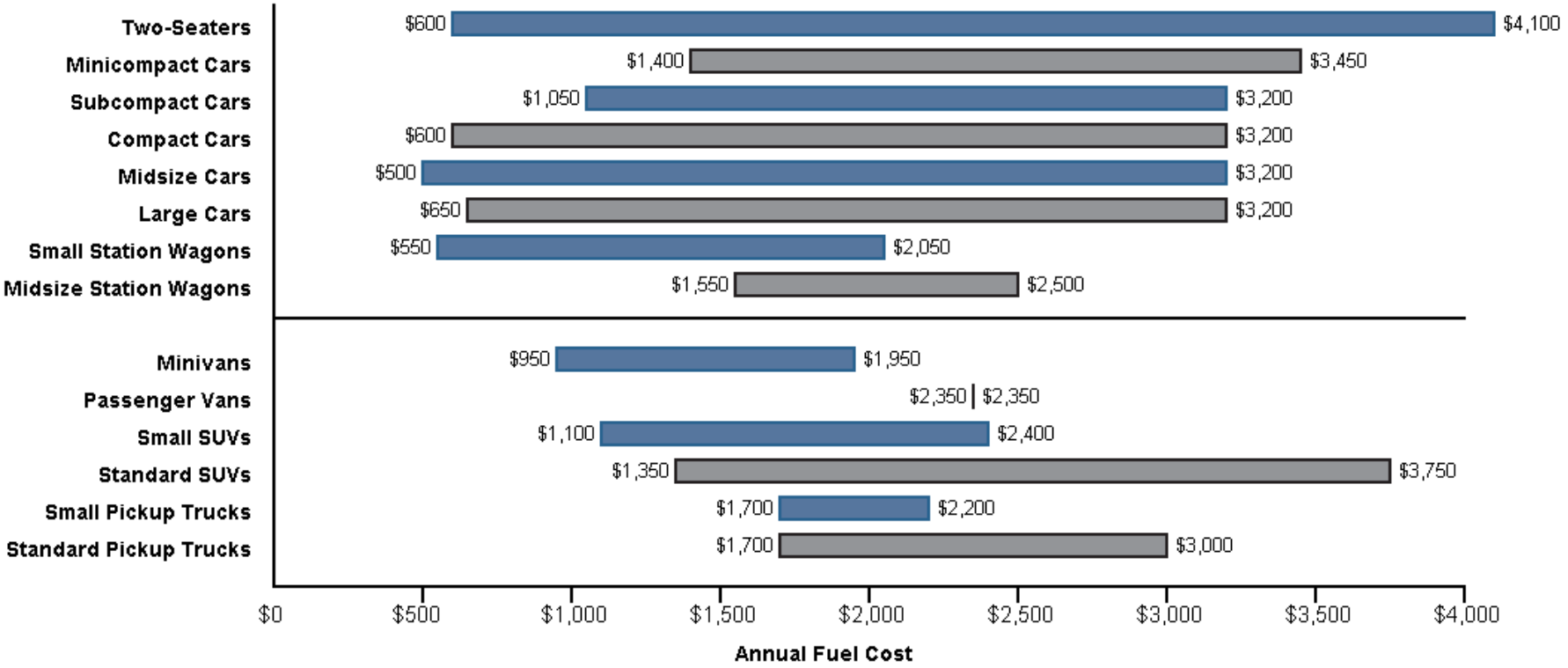


BEV fuel economy (modeled)

Source: http://trrjournalonline.trb.org/doi/abs/10.3141/2628-07

vehicle costs

DOE/EPA: Annual fuel costs for MY2018 vehicles range from $500 to over $4,000

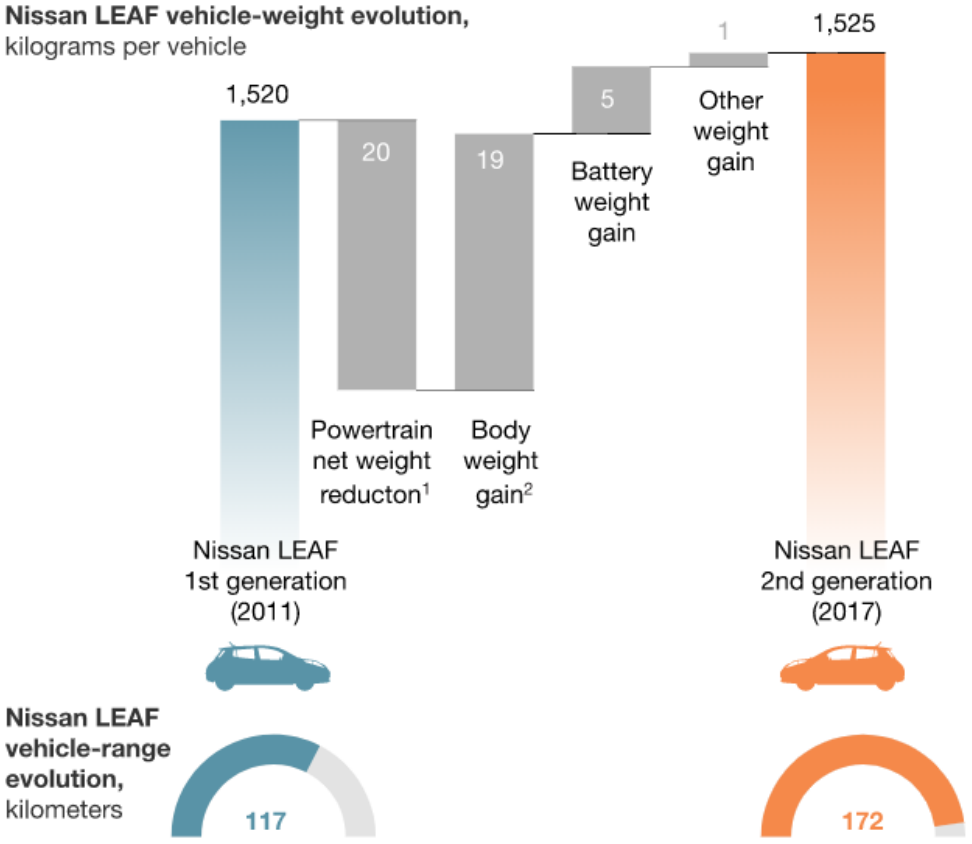


Fuel economy estimates on this chart do not include vehicles operating on compressed natural gas (CNG), E85, or hydrogen.

Source: http://fueleconomy.gov/feg/pdfs/guides/FEG2018.pdf

PEV design

McKinsey/A2Mac1: Nissan improved powertrain, but increased overall weight in second generation Leaf

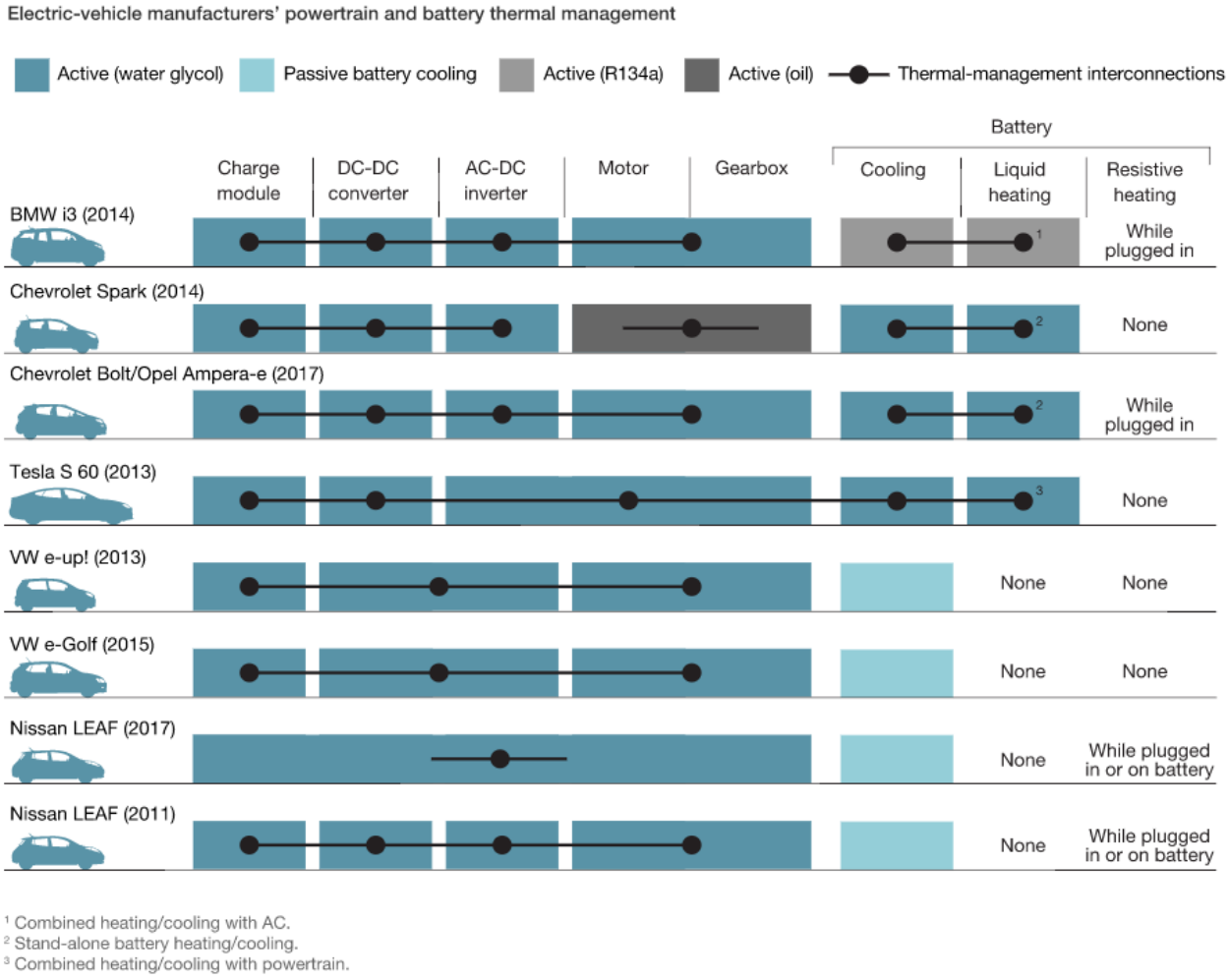


[1] Powertrain is motor, transmission system, and related electronics. Weight reduced through integration of powertrain components (inverter, converter, charger, and motor).
[2] Body weight gain from material change on doors from aluminum to steel.

Source: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/trends-in-electric-vehicle-design

PEV design

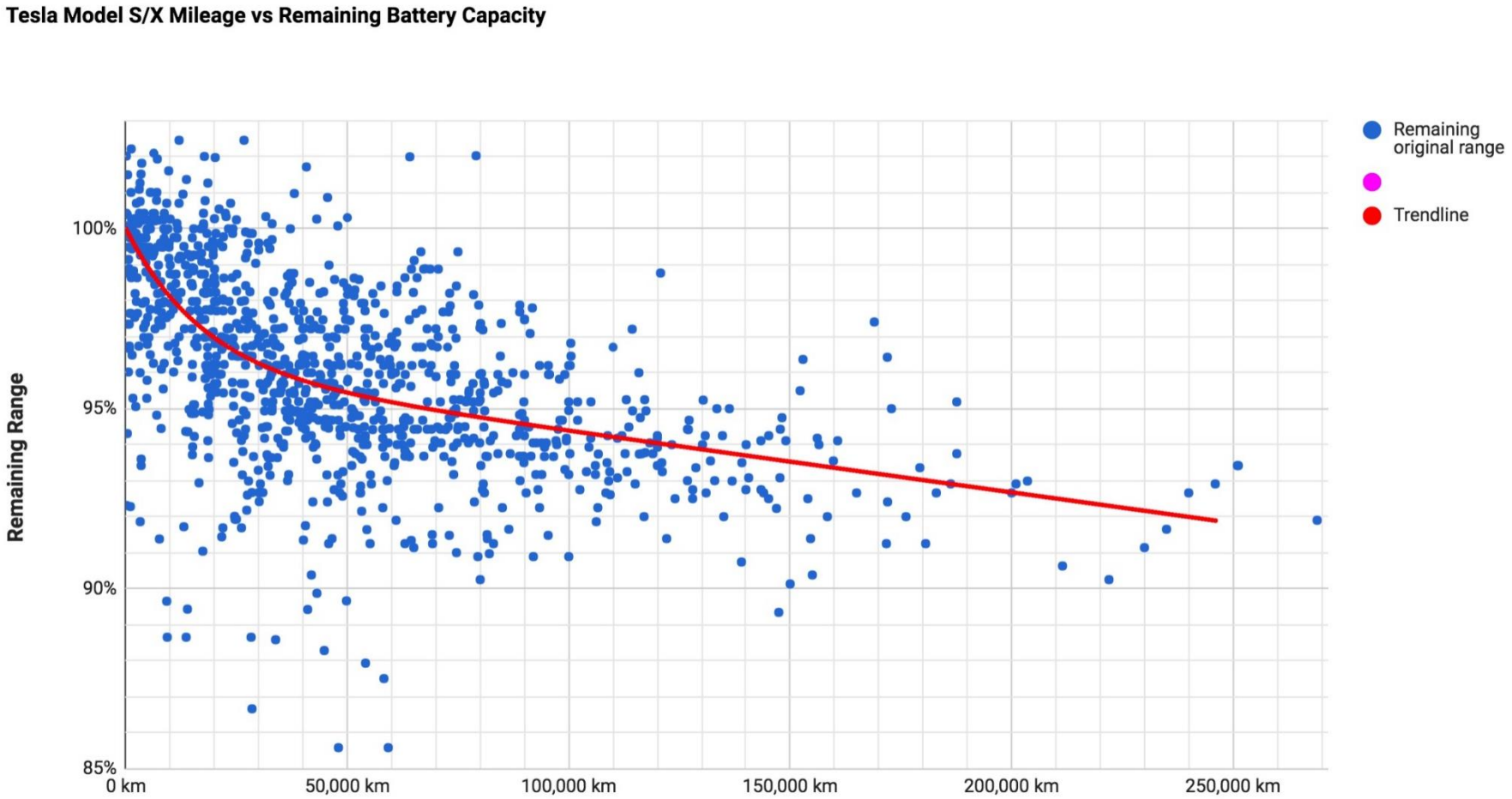
McKinsey: Design approaches to managing powertrain and battery thermal management vary widely



Source: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/trends-in-electric-vehicle-design

PEV design

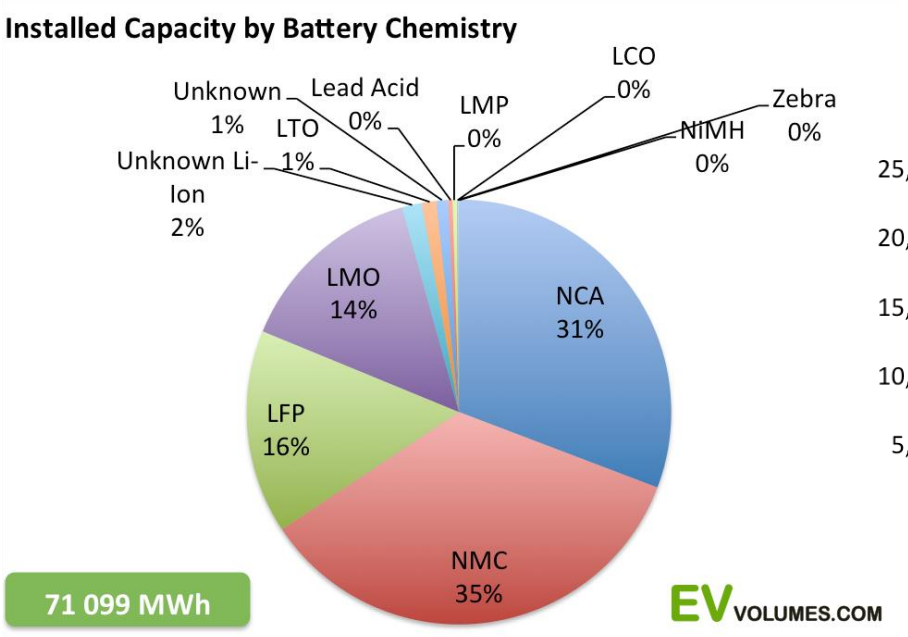
Teslarati: Tesla battery extrapolated to have over 80% capacity after 500,000 miles based on driver survey

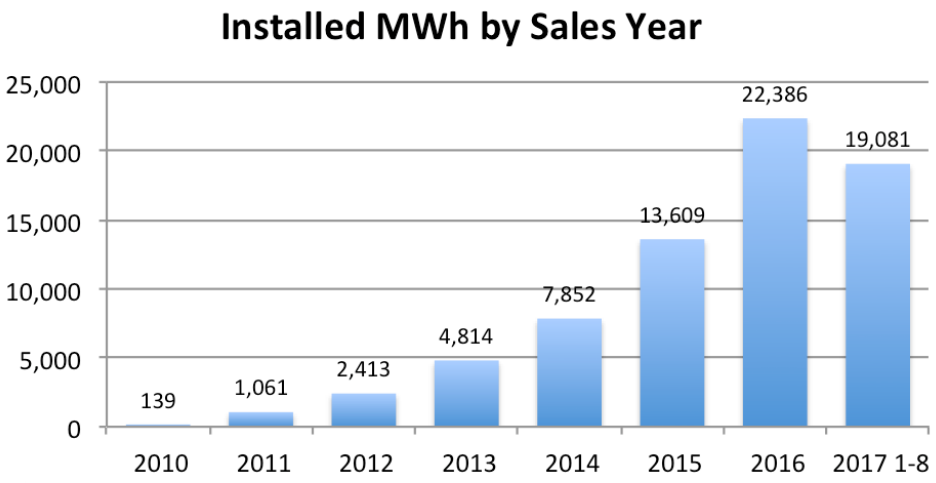


Source: https://www.teslarati.com/tesla-battery-life-80-percent-capacity-840km-1-million-km/

PEV design

EV Volumes: NMC is now the most common battery chemistry in on-road PEVs worldwide

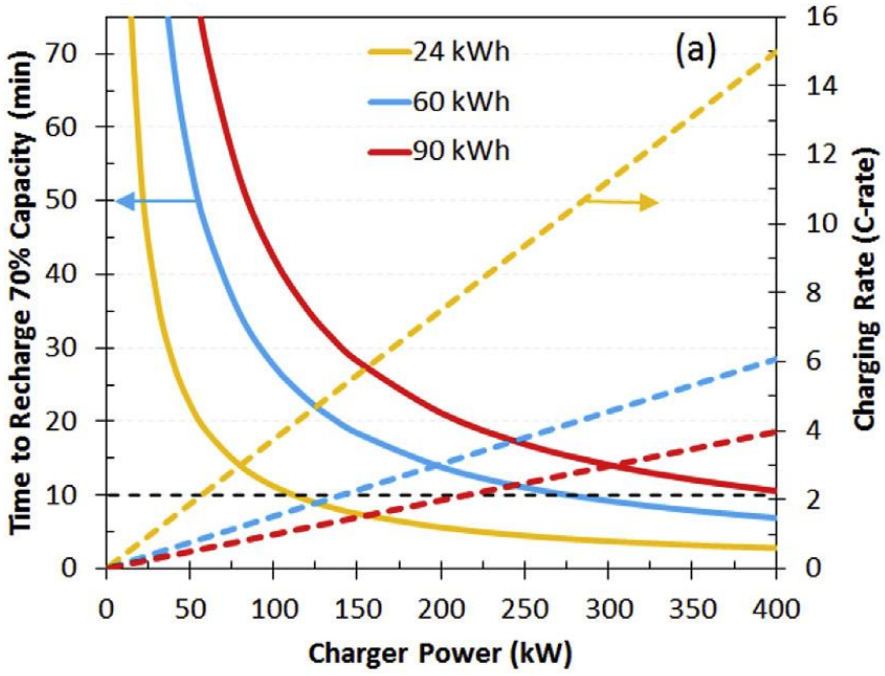


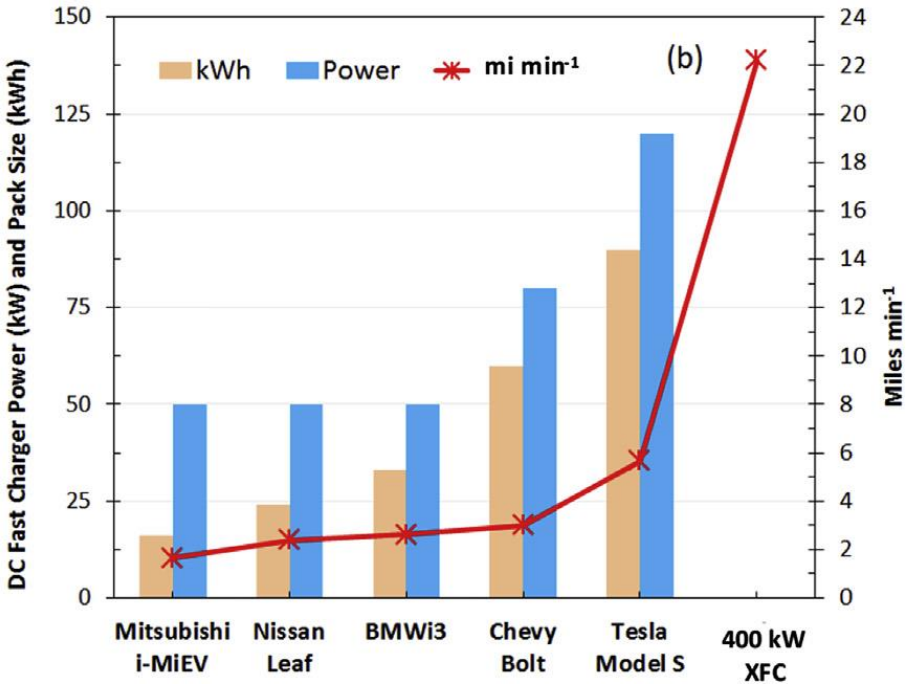


Source: http://www.ev-volumes.com/news/global-plug-in-vehicle-sales-for-2017-h1-july-august-update/

PEV charging

DOE/INL/ANL/NREL: Increasing EVSE charger power lowers PEV recharging time and increases charging rate

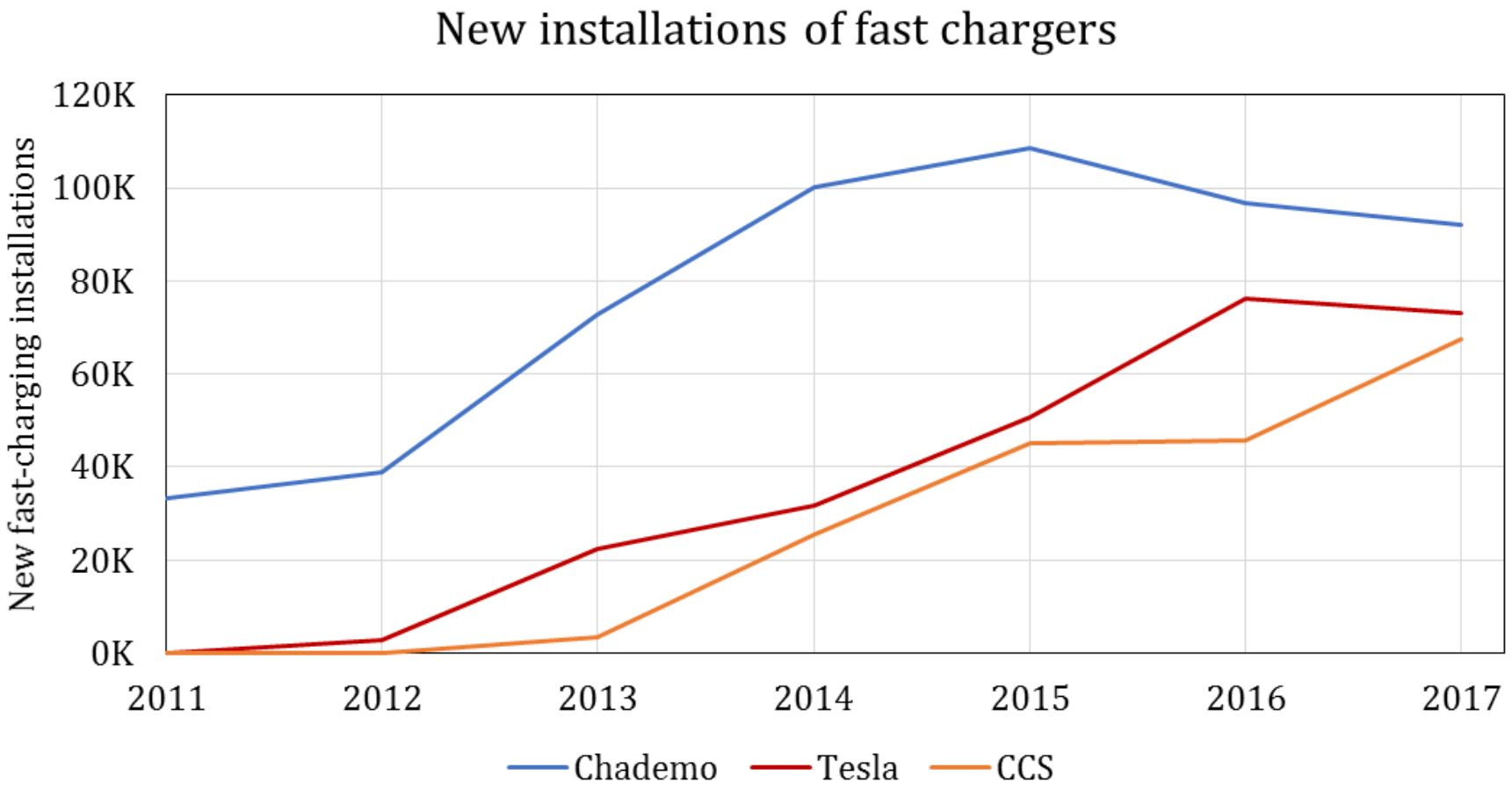




Source: https://energy.gov/eere/vehicles/downloads/enabling-extreme-fast-charging-technology-gap-assessment

PEV charging

EV Sales: Combined Charging System (CCS) chargers are rapidly gaining market share relative to CHAdeMO



Source: http://ev-sales.blogspot.com/2017/10/fast-charging-ev-stock-q3-2017.html

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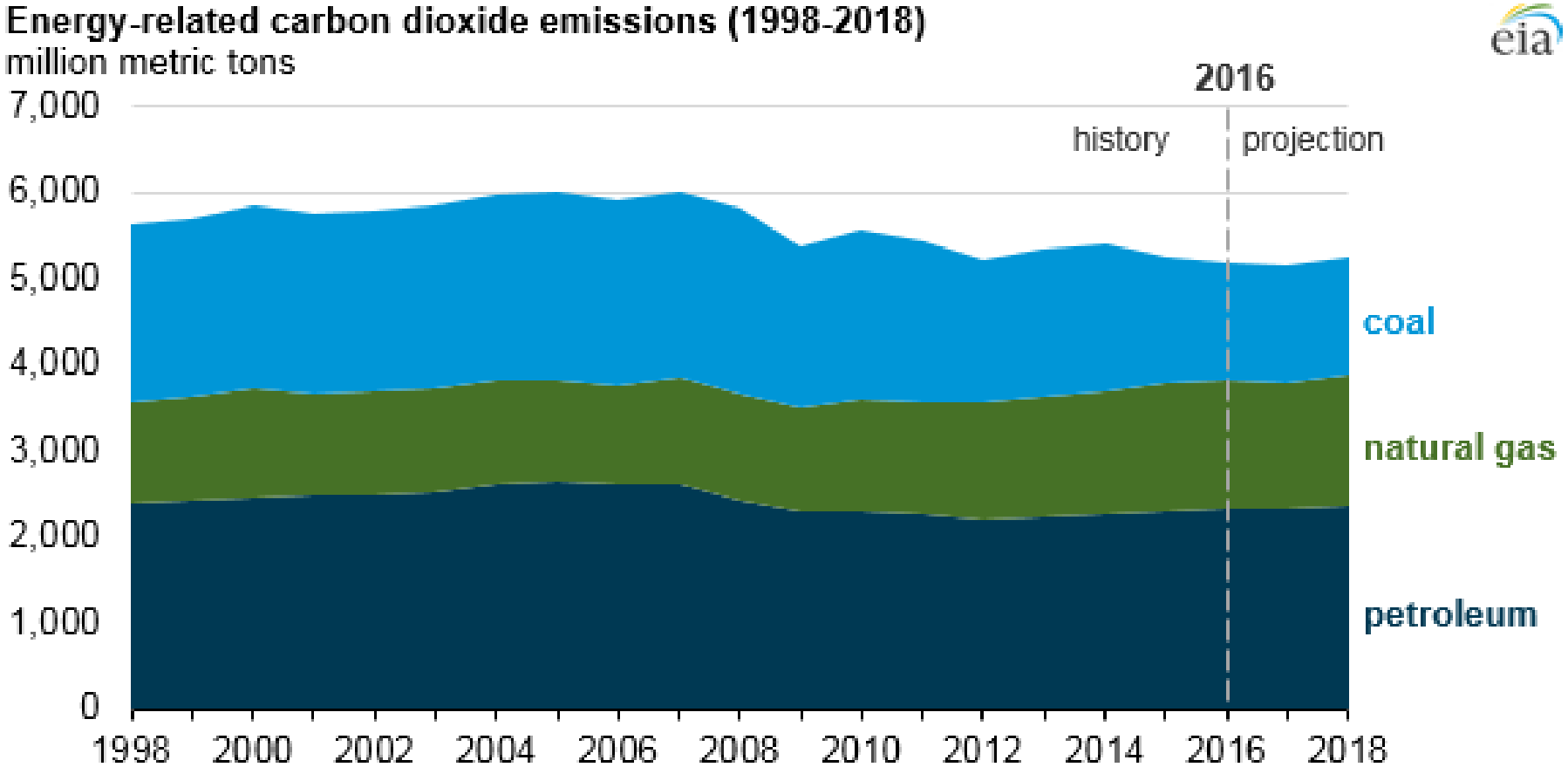
emissions

- EIA: U.S. energy-related CO2 emissions fell in 2015, 2016, and probably 2017
- WMO: Total atmospheric GHGs reached record levels in 2016
- ExxonMobil: Improved gasoline vehicles are currently a cost-effective option to reduce carbon emissions

emissions

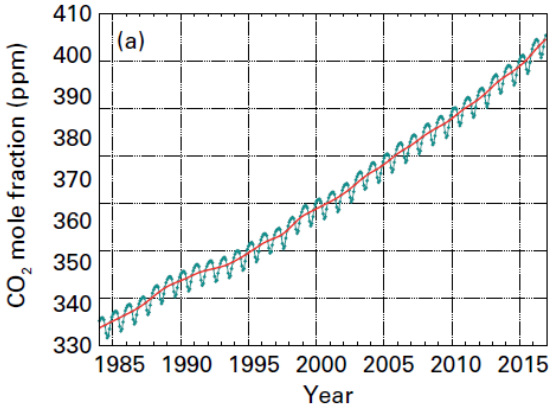
EIA: U.S. energy-related CO_2 emissions fell in both 2015 and 2016, and they are expected to fall again in 2017

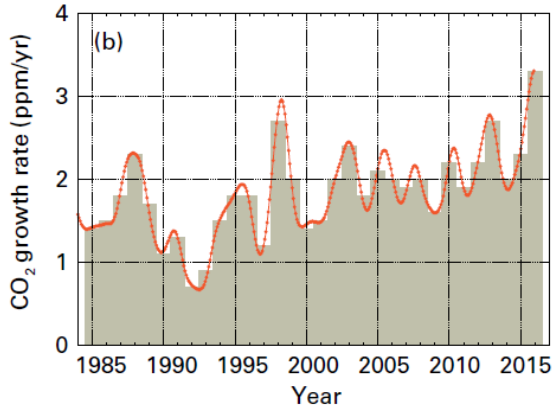


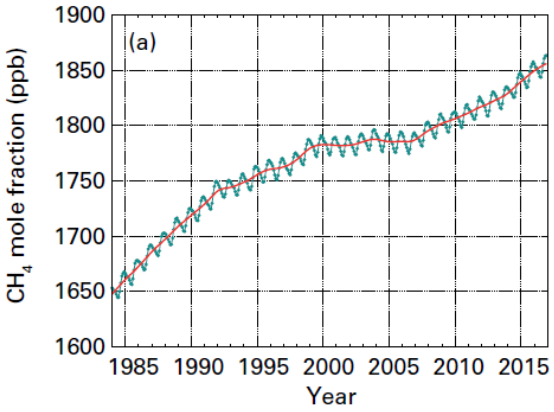
Source: https://www.eia.gov/todayinenergy/detail.php?id=33292

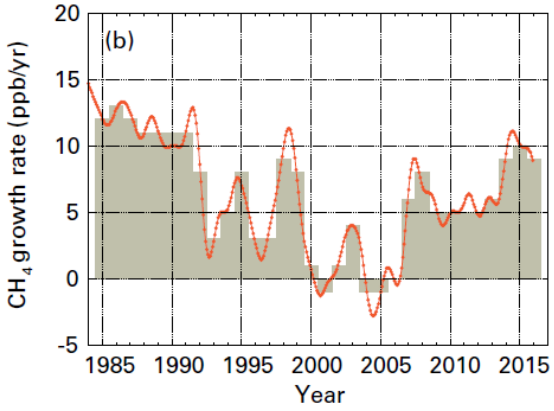
emissions

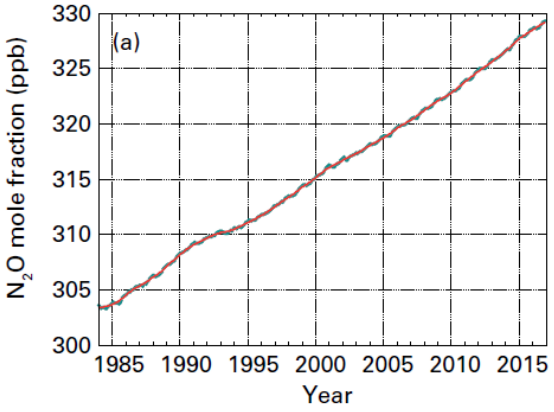
WMO: Total atmospheric CO_2, CH_4, and N_2O reached record levels in 2016; CO_2 emissions at record high

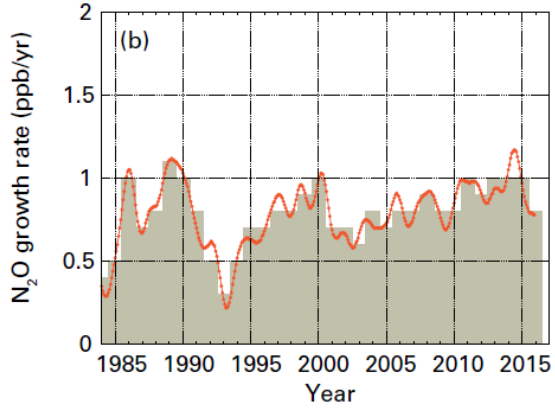








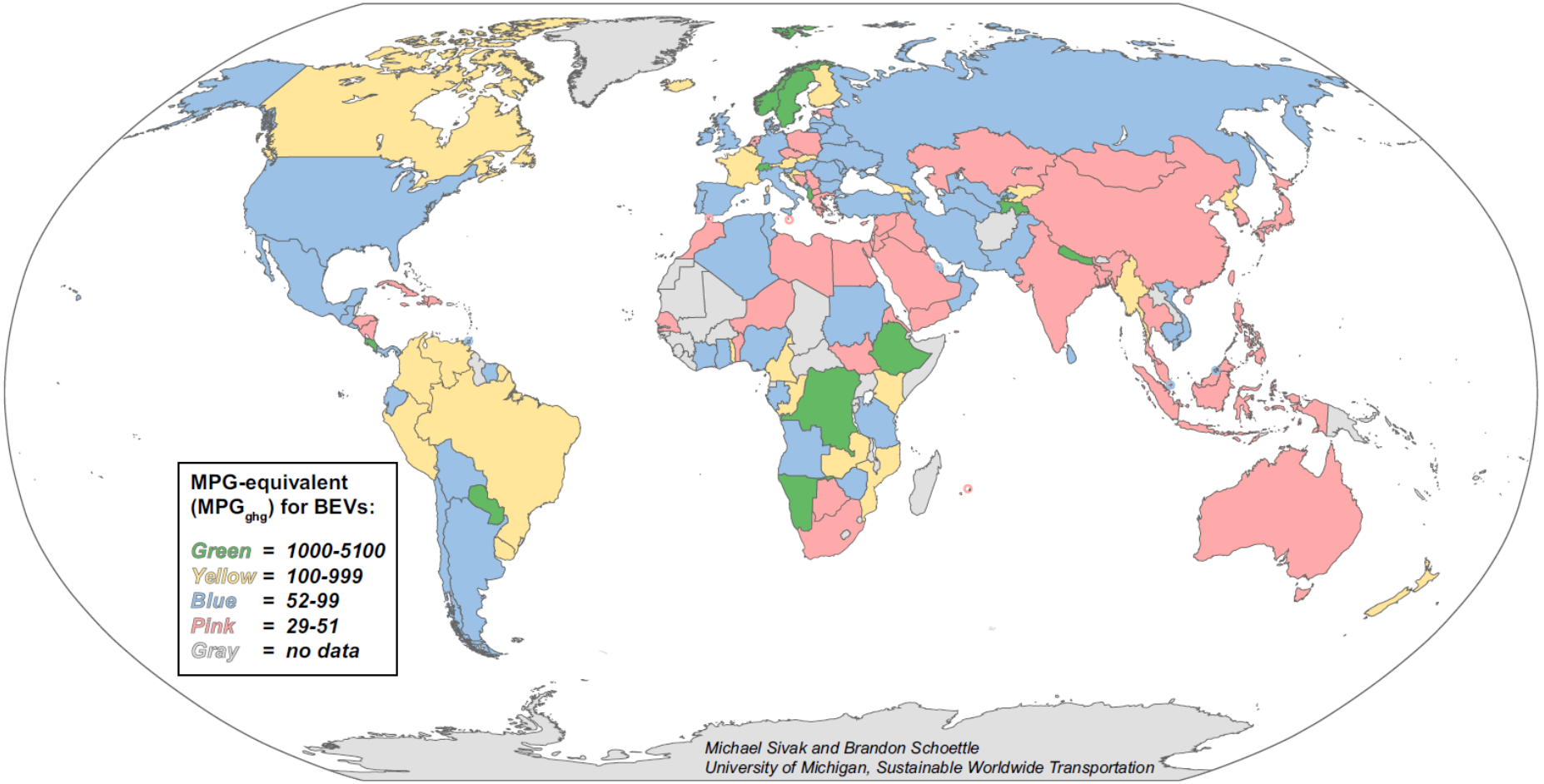




Source: https://public.wmo.int/en/media/press-release/greenhouse-gas-concentrations-surge-new-record

emissions

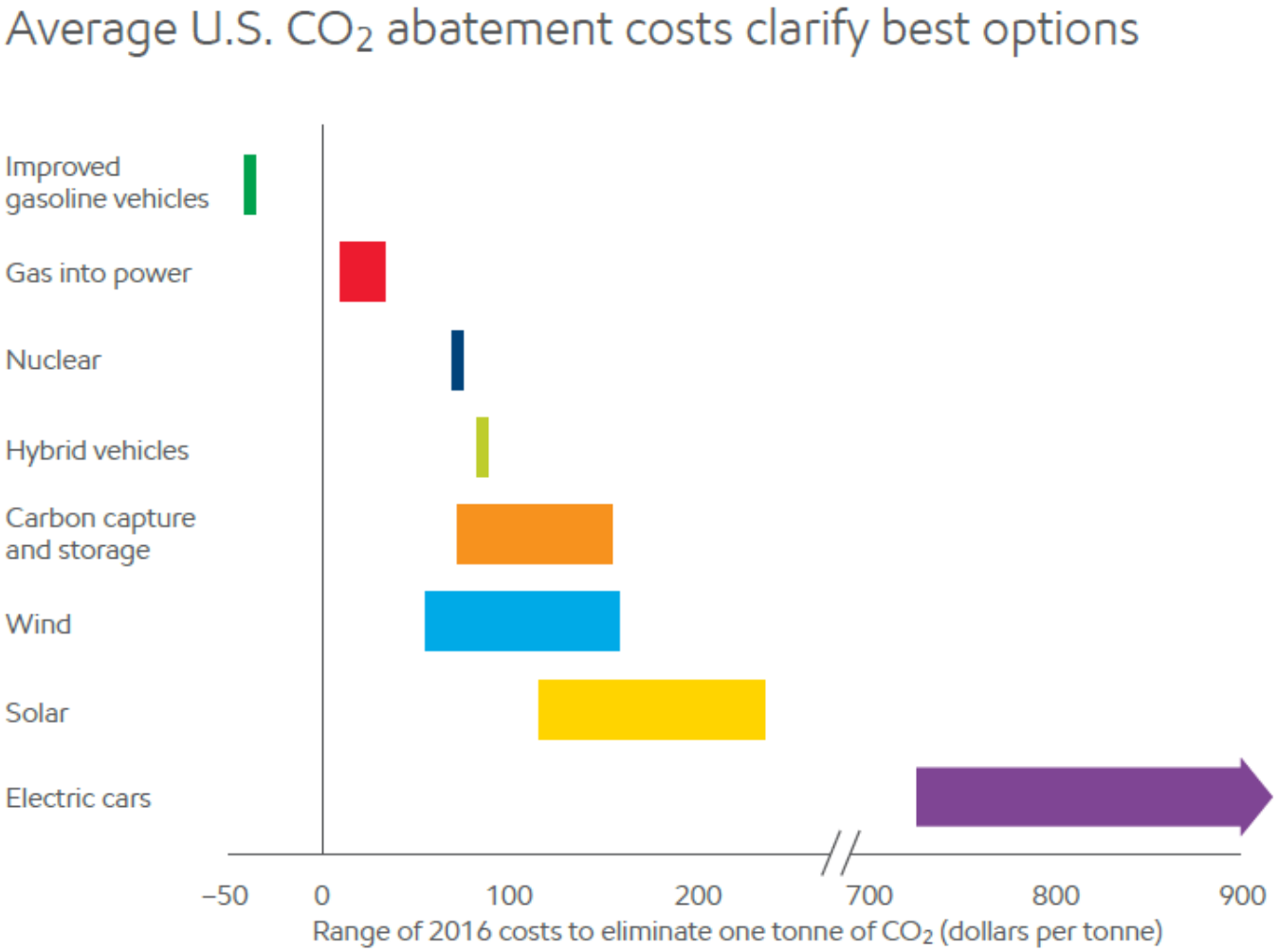
UM: Differences in electric generation lead to large differences in GHG emissions from PEVs by country



Source: http://www.umich.edu/~umtriswt/PDF/SWT-2017-18_Abstract_English.pdf

carbon abatement

ExxonMobil: Improved gasoline vehicles are currently a cost-effective option to reduce carbon emissions



Source: http://corporate.exxonmobil.com/en/energy/energy-outlook/download-the-report/download-the-outlook-for-energy-reports

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ride-hailing

> UCD: Multi-tasking not currently an important reason for ride-hailing

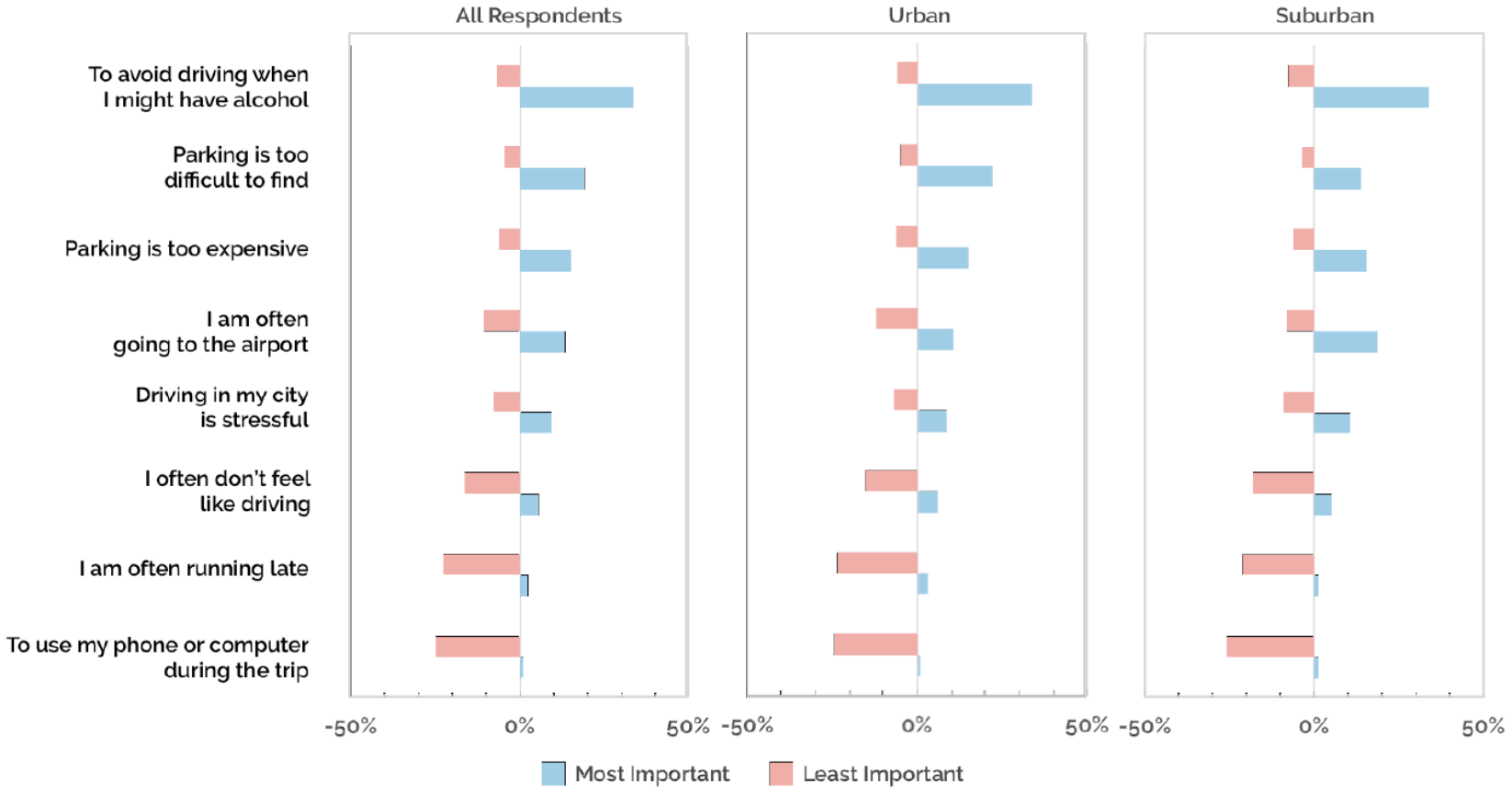
PEV sentiments

> NREL: Awareness of EV charging infrastructure is growing; awareness is correlated with greater likelihood to consider buying PEV

ride-hailing

UC Davis: Avoiding drunk driving is a top motivator for current ride-hailing users; multitasking is less important

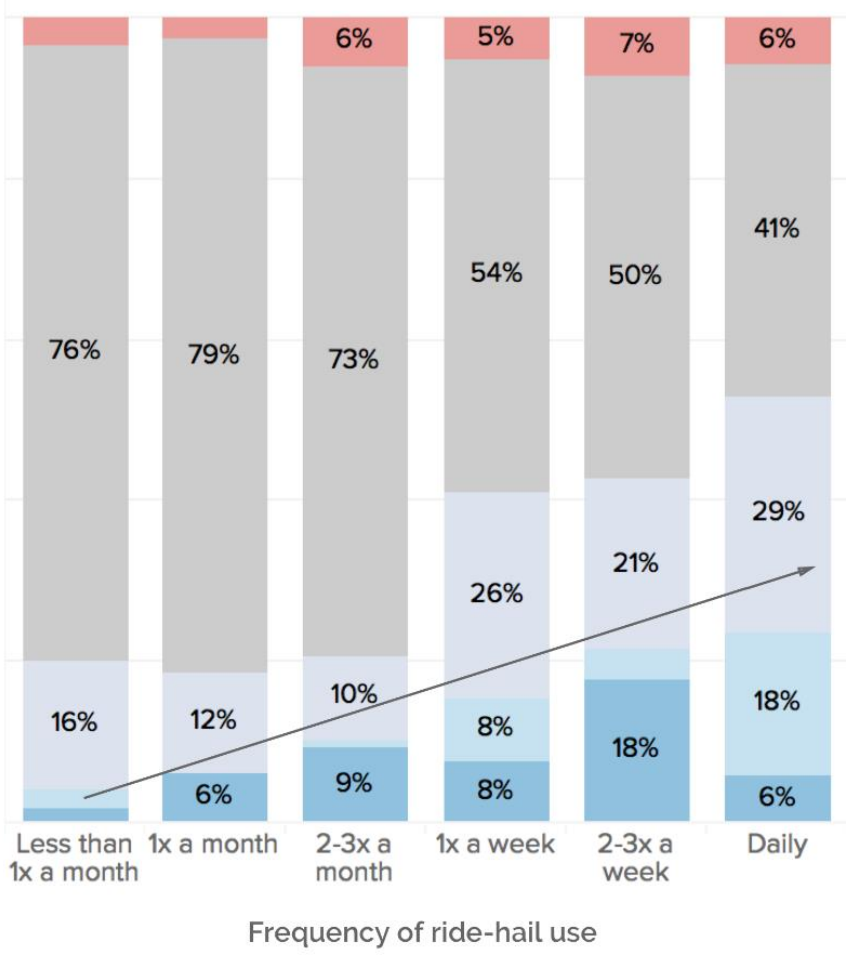
Figure 4. Reasons for using ride-hailing services instead of driving oneself

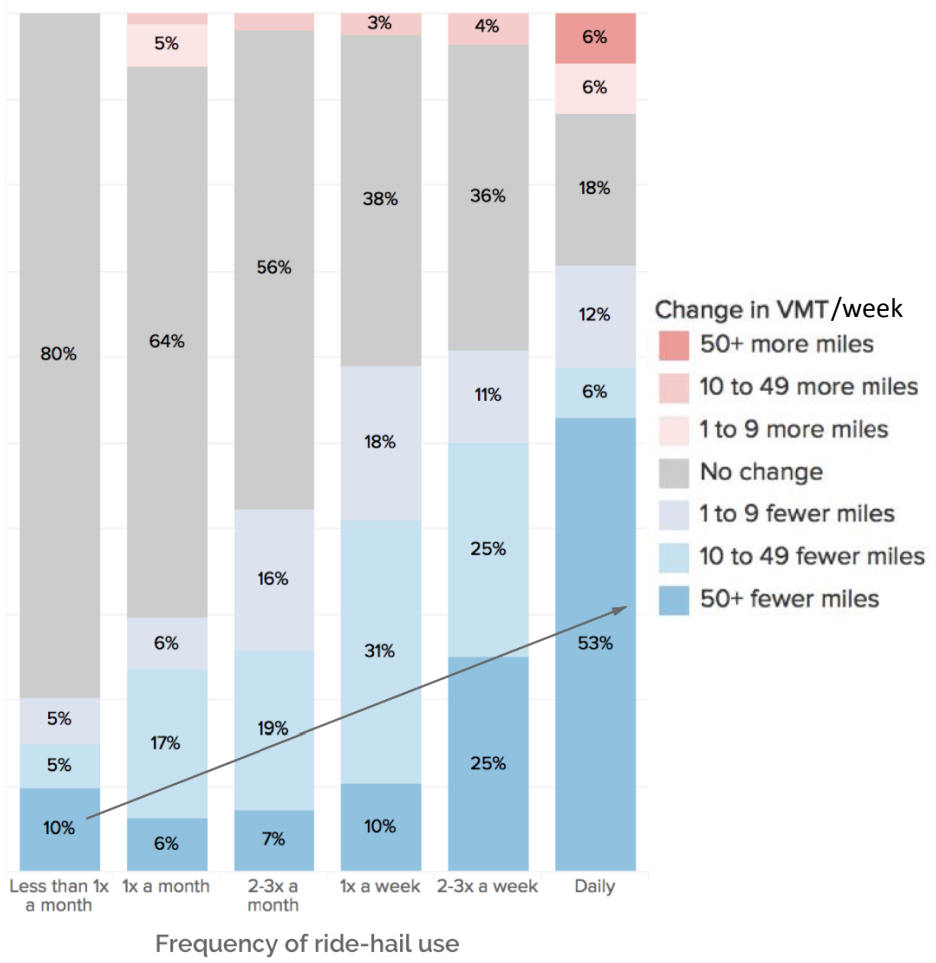


Source: https://itspubs.ucdavis.edu/wp-content/themes/ucdavis/pubs/download_pdf.php?id=2752

ride-hailing

UC Davis: Increased ride-hailing use correlates with reduced vehicle ownership and reduced personal VMT

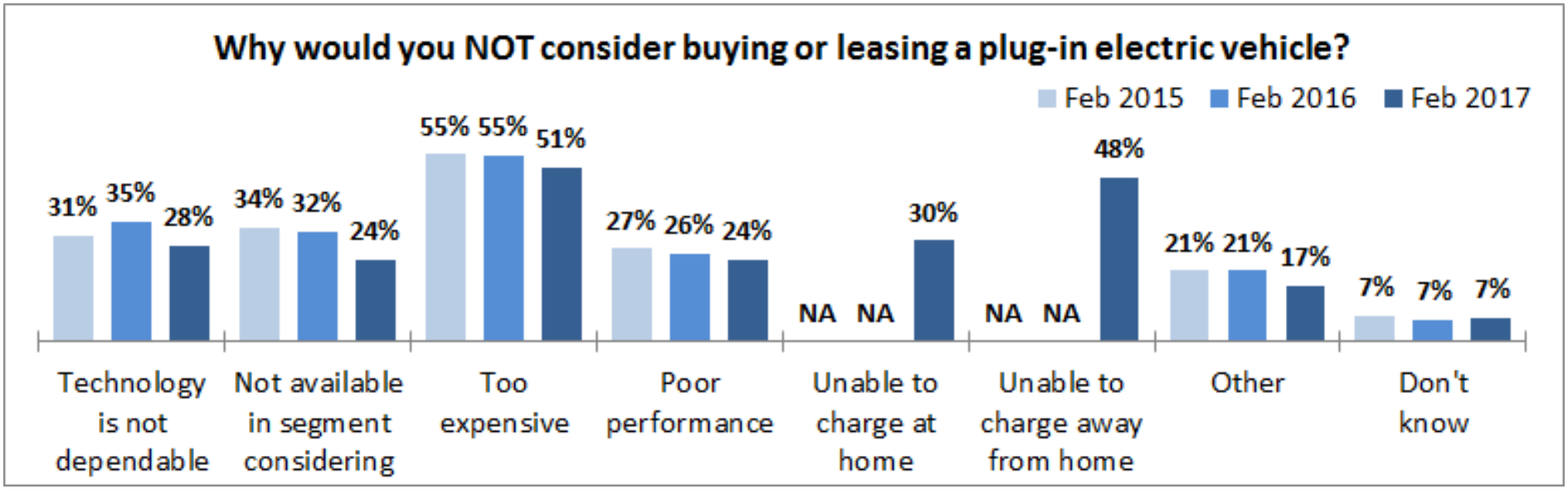




Source: https://itspubs.ucdavis.edu/wp-content/themes/ucdavis/pubs/download_pdf.php?id=2752

PEV sentiments

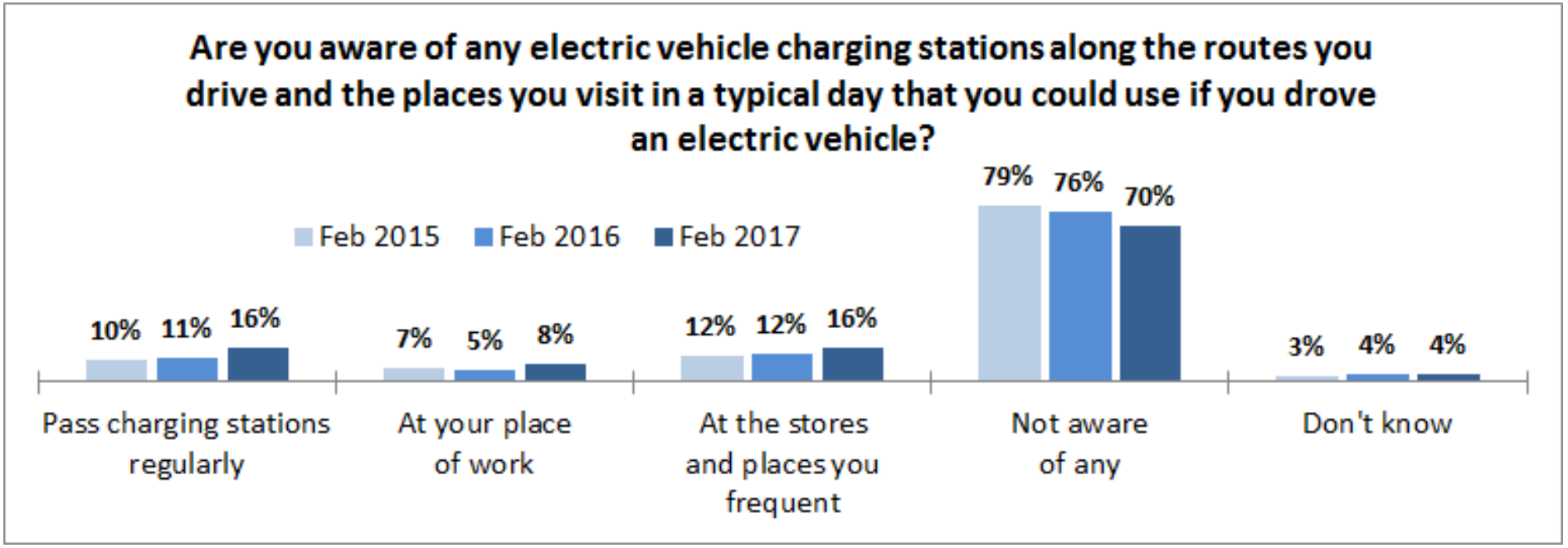
NREL: Availability of PEVs is becoming less of a barrier for adoption; charging infrastructure is still important



Source: https://www.nrel.gov/docs/fy18osti/70371.pdf

PEV sentiments

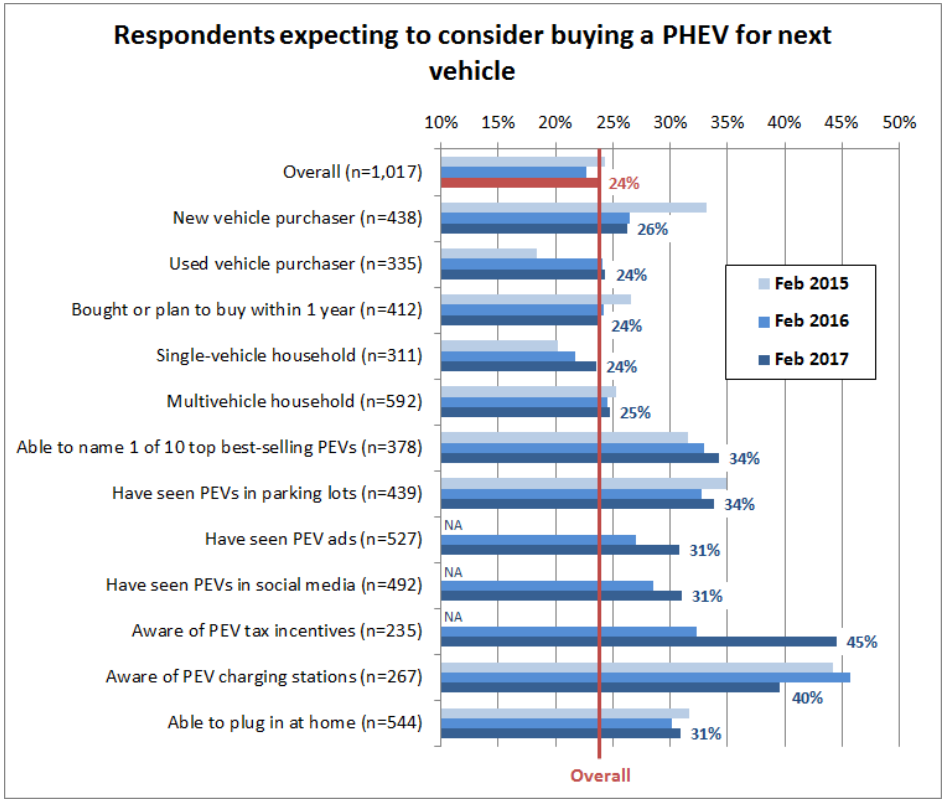
NREL: Awareness of electric-vehicle charging infrastructure is growing

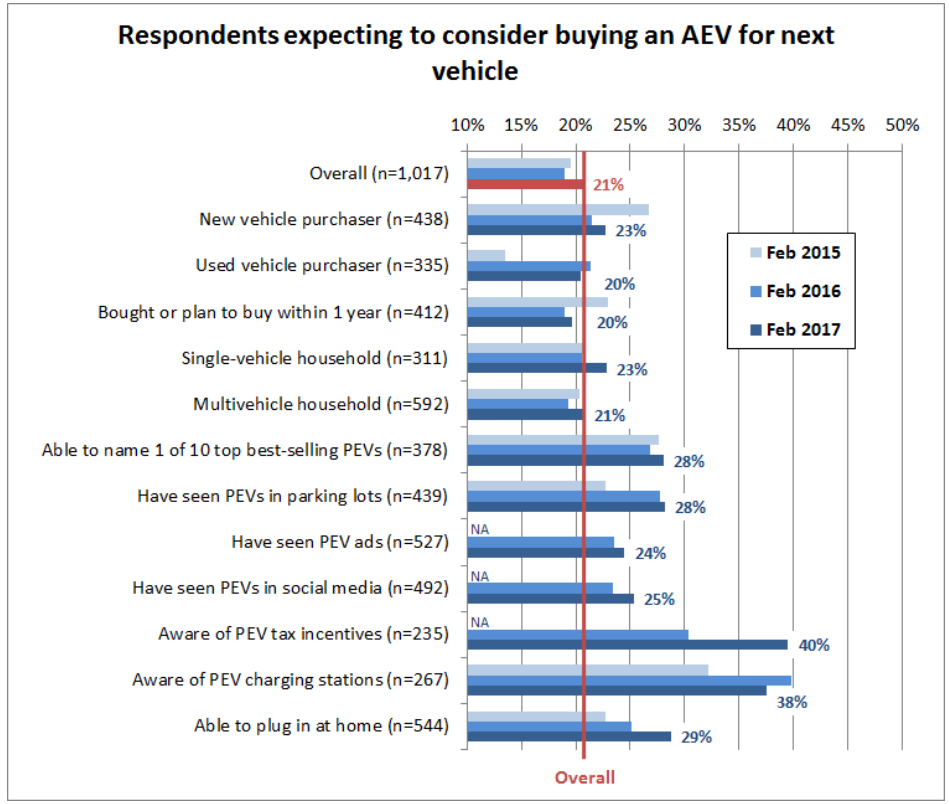


Source: https://www.nrel.gov/docs/fy18osti/70371.pdf

PEV sentiments

NREL: Awareness of charging infrastructure and tax incentives is correlated with considering PEV purchase





Source: https://www.nrel.gov/docs/fy18osti/70371.pdf

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vehicle design

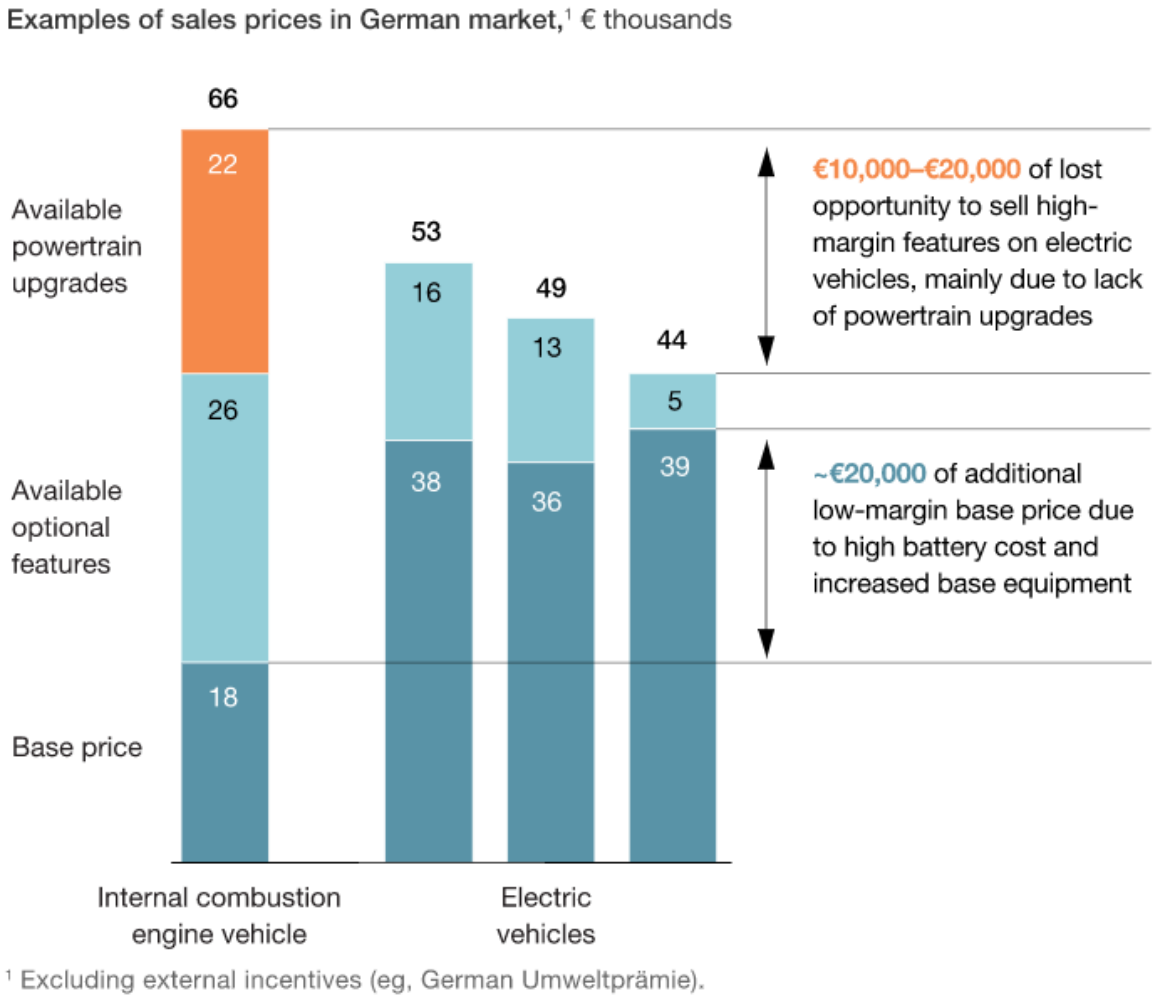
> McKinsey: PEVs give OEMs less opportunity to make money on upgrades and options

MaaS

> OPEC: Mobility-as-a-Service can reduce oil demand in both OECD and China by over 10% in 2040
> PwC: Half of LDV person-miles will be shared or autonomous by 2030

vehicle design

McKinsey: PEVs afford OEMs less opportunity to make money on powertrain upgrades and optional features



Source: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/trends-in-electric-vehicle-design

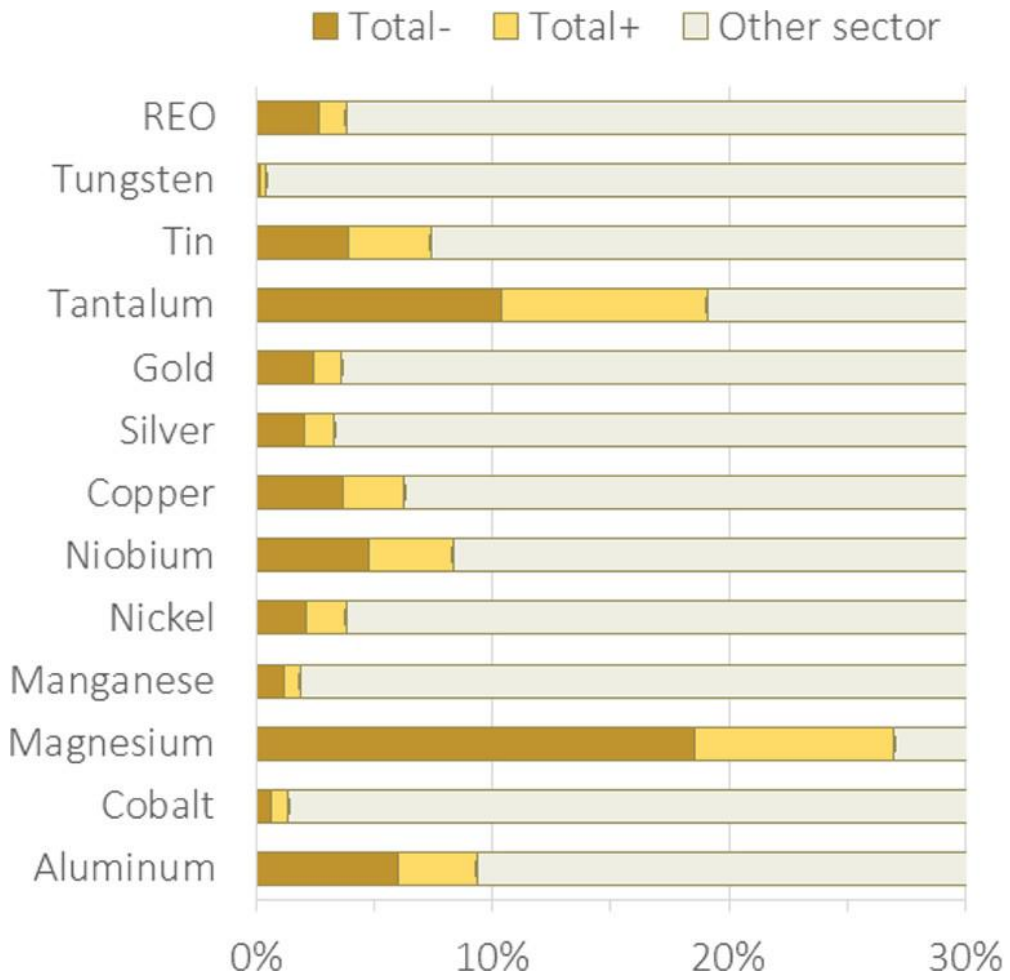
vehicle design

Bloomberg: Recent increases in lithium and cobalt prices are projected to slow in next five years

Source: https://www.bloomberg.com/news/articles/2017-12-01/the-cobalt-crunch-for-electric-cars-could-be-solved-in-suburbia

vehicle design

MIT/Ford: Vehicle manufacturing uses a large portion of world's magnesium and tantalum



Source: http://pubs.acs.org/doi/10.1021/acs.est.6b06063

EV credits

CSE: Rebates for PEV buyers in California were less important to early purchasers

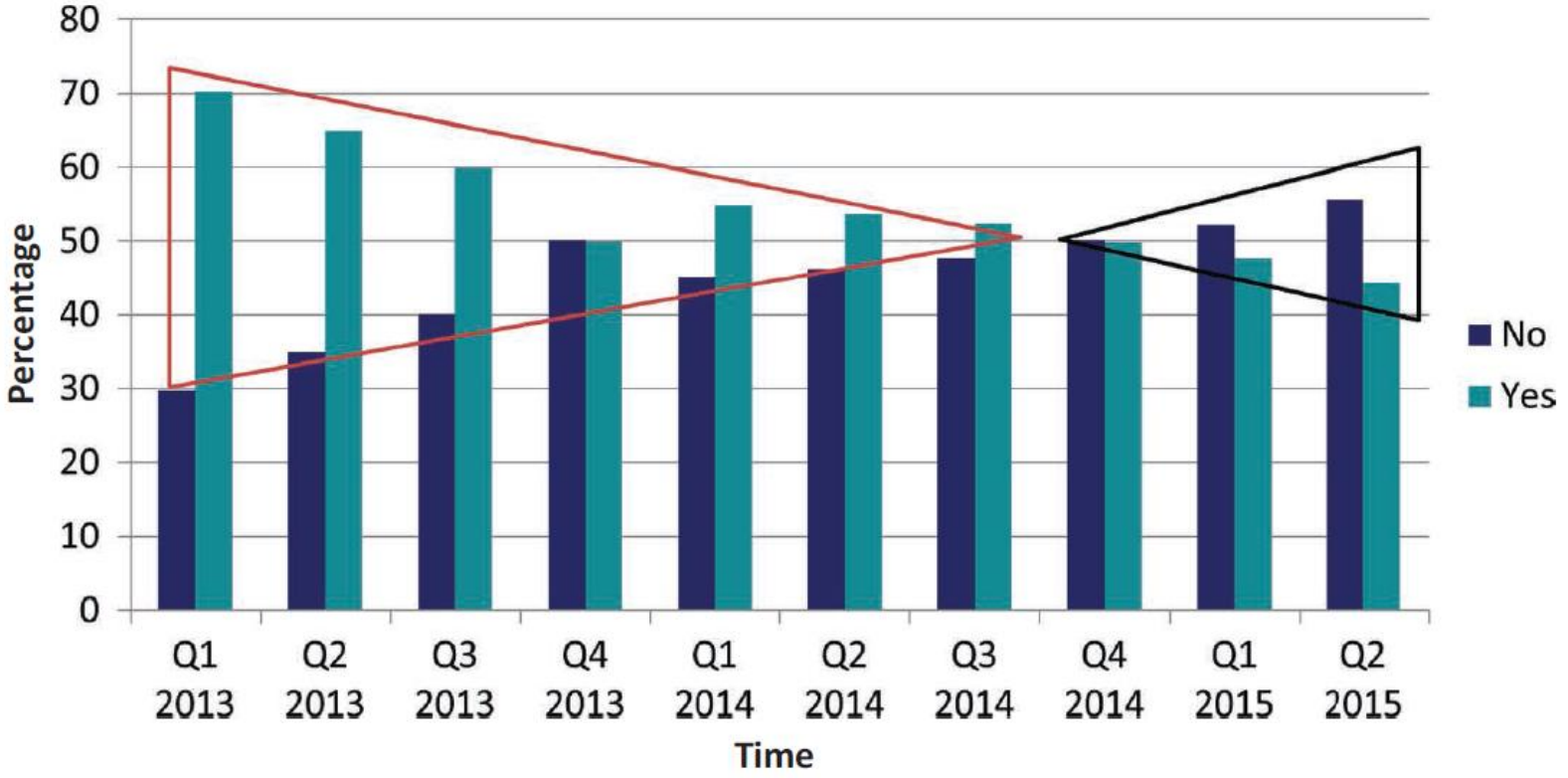
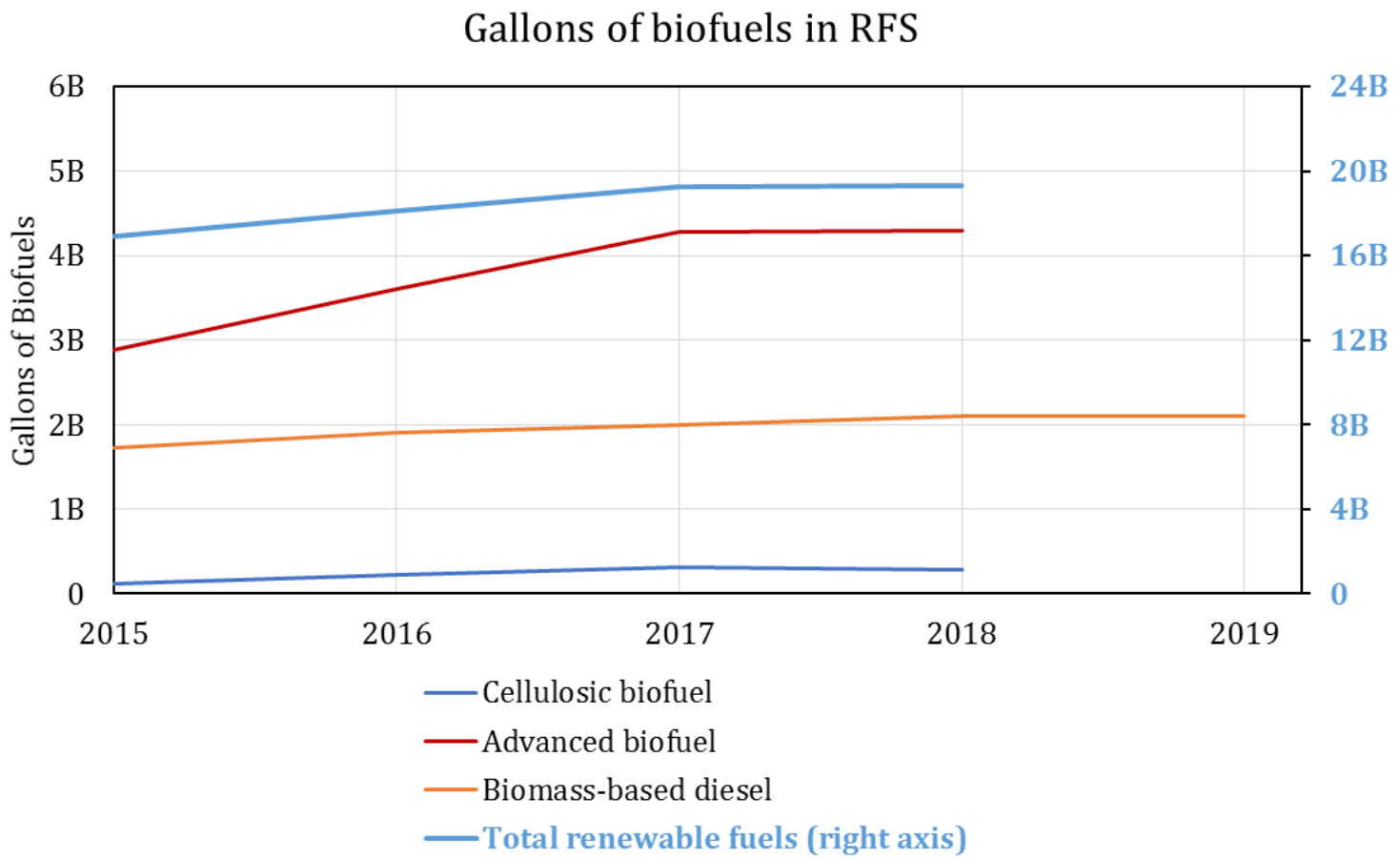


FIGURE 1 Participant-rated influence of the CVRP rebate over time shown by participant response to the question, "Would you have purchased or leased your vehicle without the state vehicle (CVRP) rebate?" (*10*).

Source: http://trrjournalonline.trb.org/doi/abs/10.3141/2628-03

policies

EPA: RFS biofuels standards will be mostly the same in 2018 as in 2017

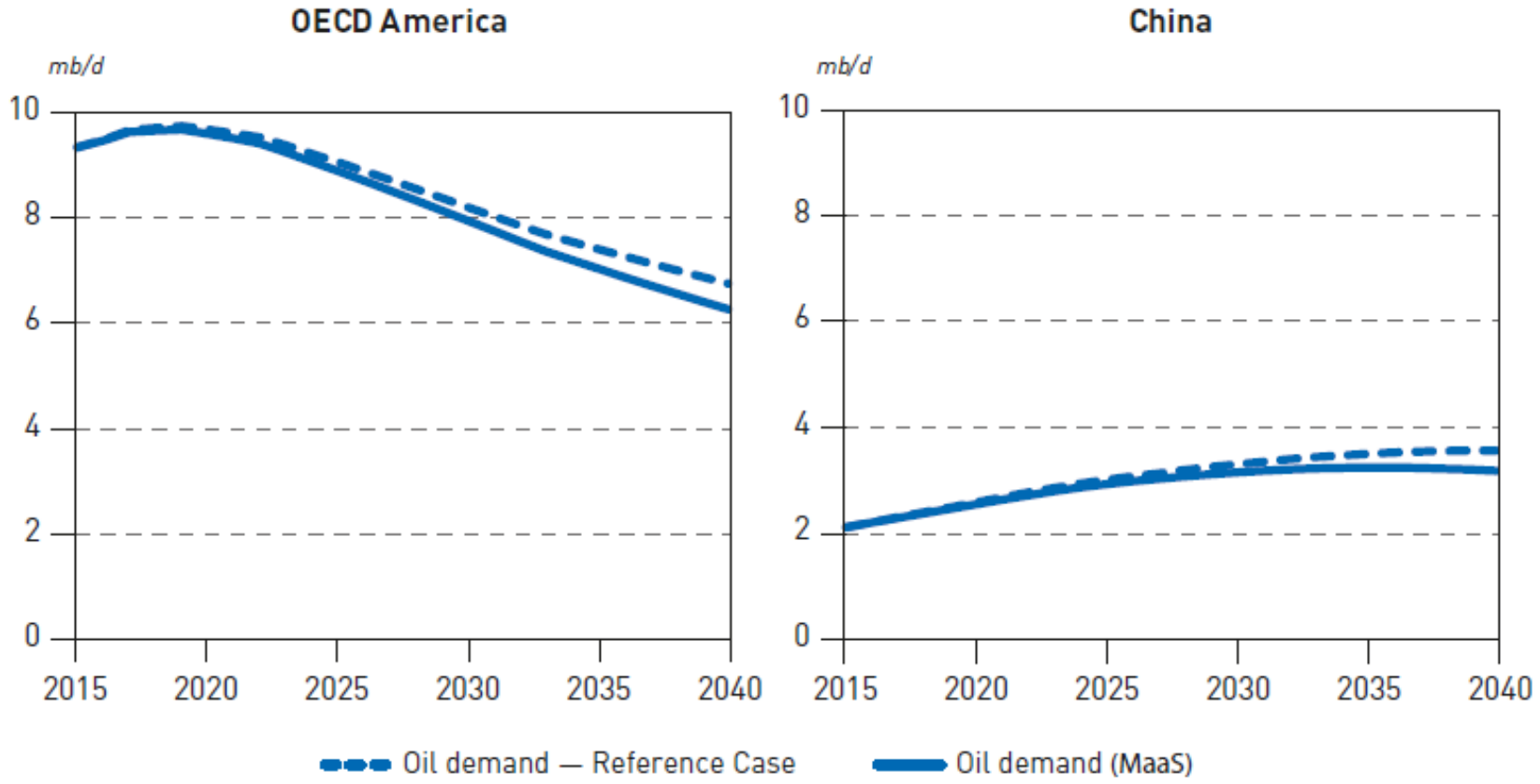


Source: https://www.epa.gov/renewable-fuel-standard-program/final-renewable-fuel-standards-2018-and-biomass-based-diesel-volume and http://www.nacsonline.com/Media/Daily/Pages/ND1201172.aspx

mobility-as-a-service

OPEC: Mobility-as-a-Service can reduce oil demand in both OECD and China by over 10% in 2040

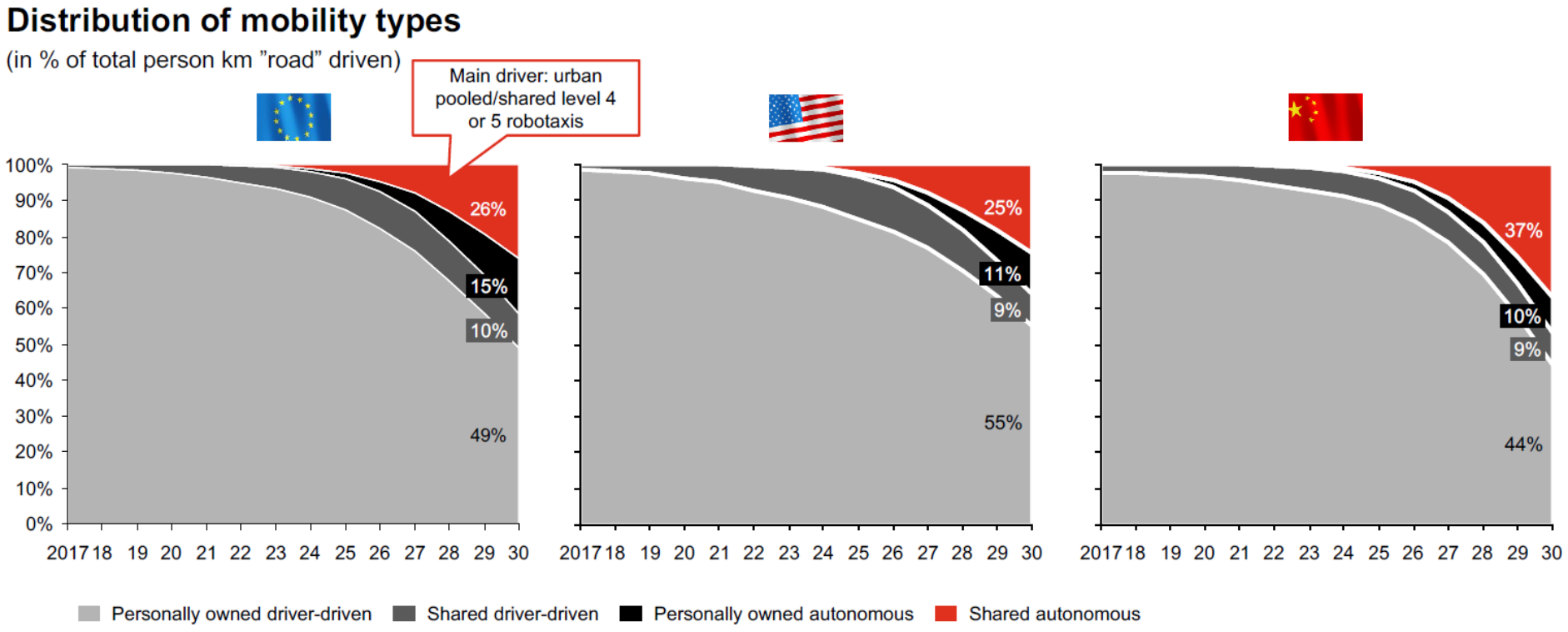
Oil demand in the passenger car segment in the Reference Case (dotted line) and in the MaaS case (solid line)



Source: https://woo.opec.org/

mobility-as-a-service

PwC: Half of LDV person-miles will be shared or autonomous by 2030

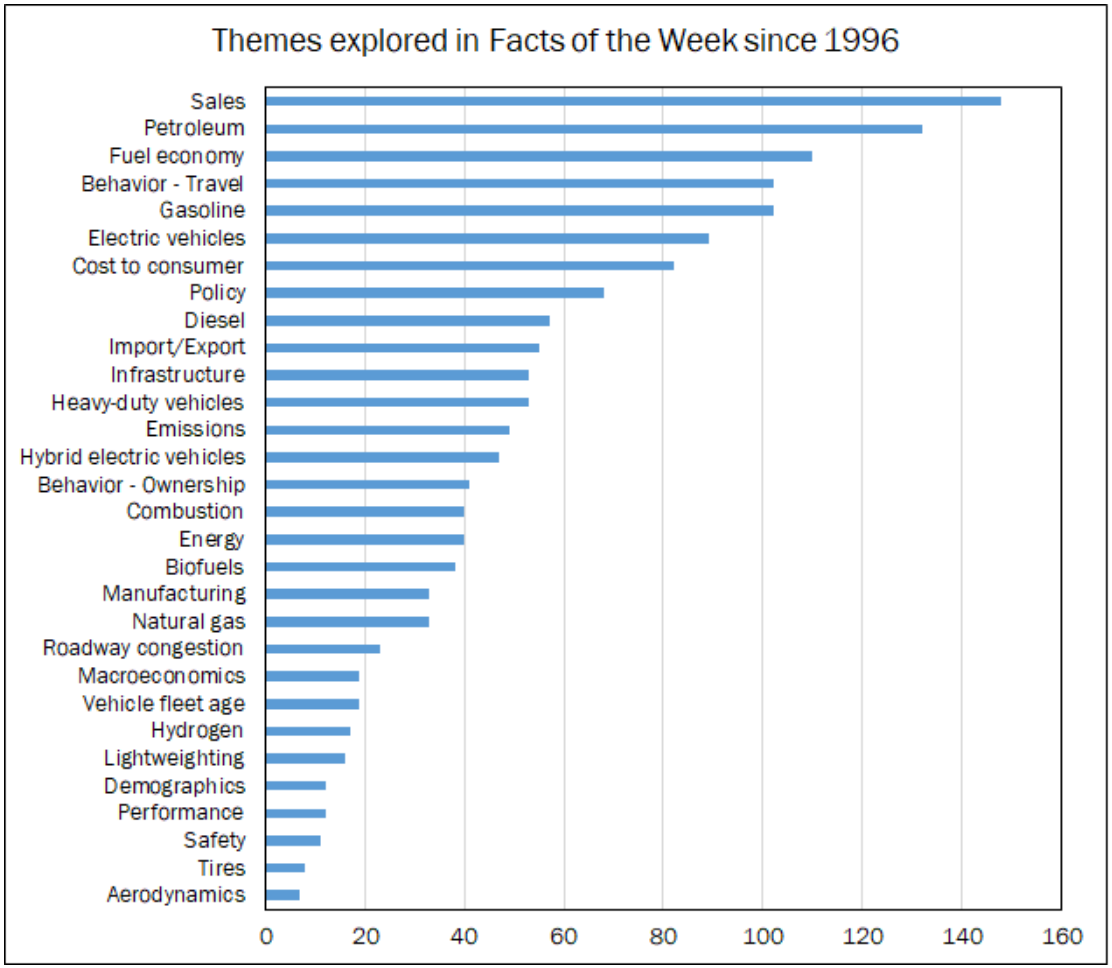


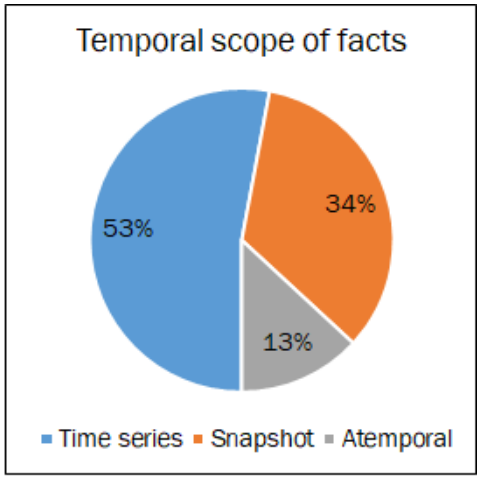
Source: PwC Autofacts; Strategy& analysis
The 2017 PwC's Strategy& Digital Auto Report

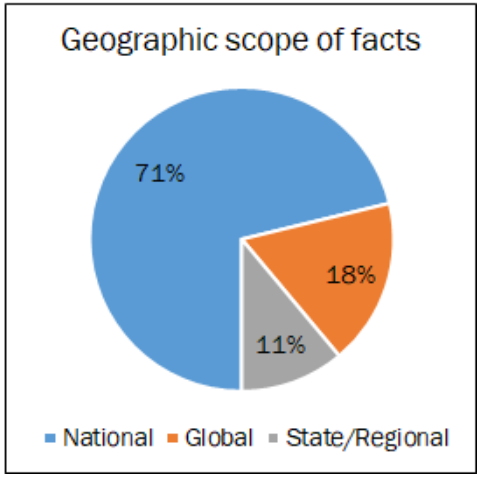
Source: https://www.strategyand.pwc.com/media/file/2017-Strategyand-Digital-Auto-Report.pdf

public communications

FOTW: One thousand transportation facts of the week have been posted online since 1996





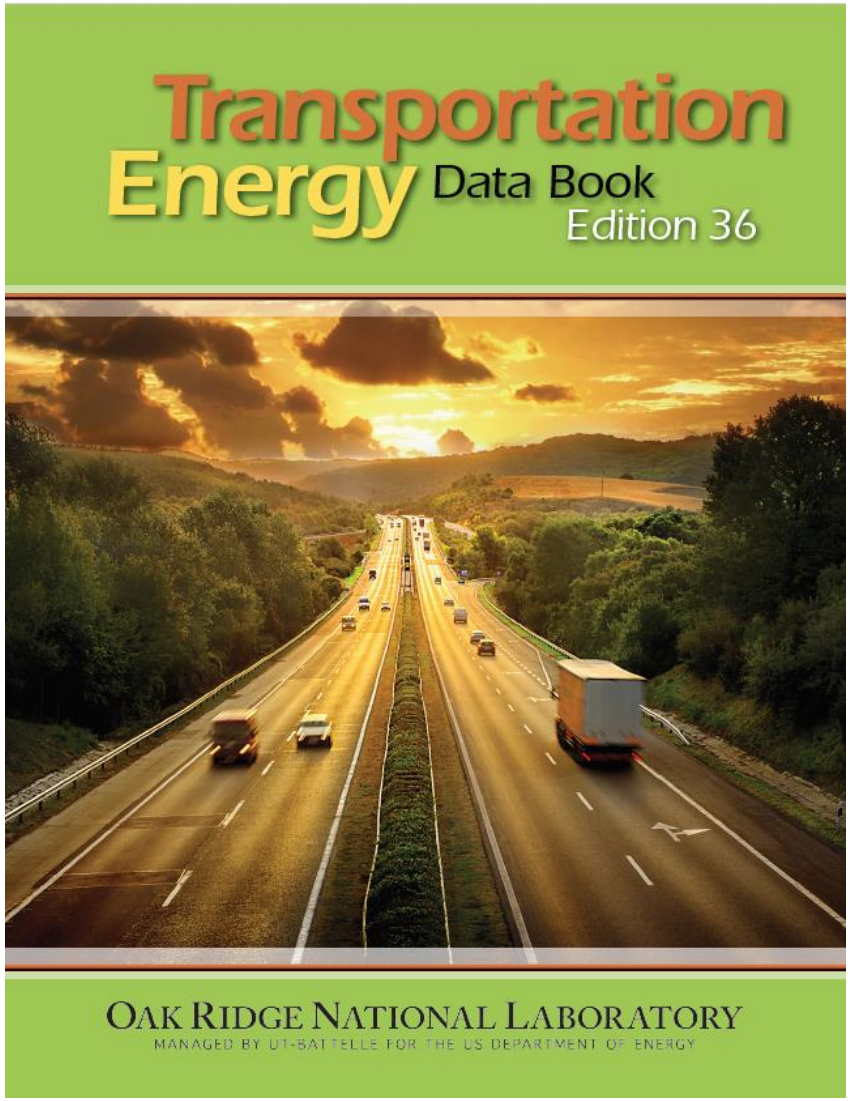


Source: https://energy.gov/eere/vehicles/articles/fotw-1001-october-30-2017-one-thousand-transportation-analysis-facts-week

publication

ORNL: *Transportation Energy Data Book, Edition 36* now online

The *Transportation Energy Data Book* (TEDB) is a compendium of data on transportation with an emphasis on energy. Designed for use as a desktop reference, the TEDB was first published in 1976 and has continued to Edition 36. The TEDB is produced by Oak Ridge National Laboratory for the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy.

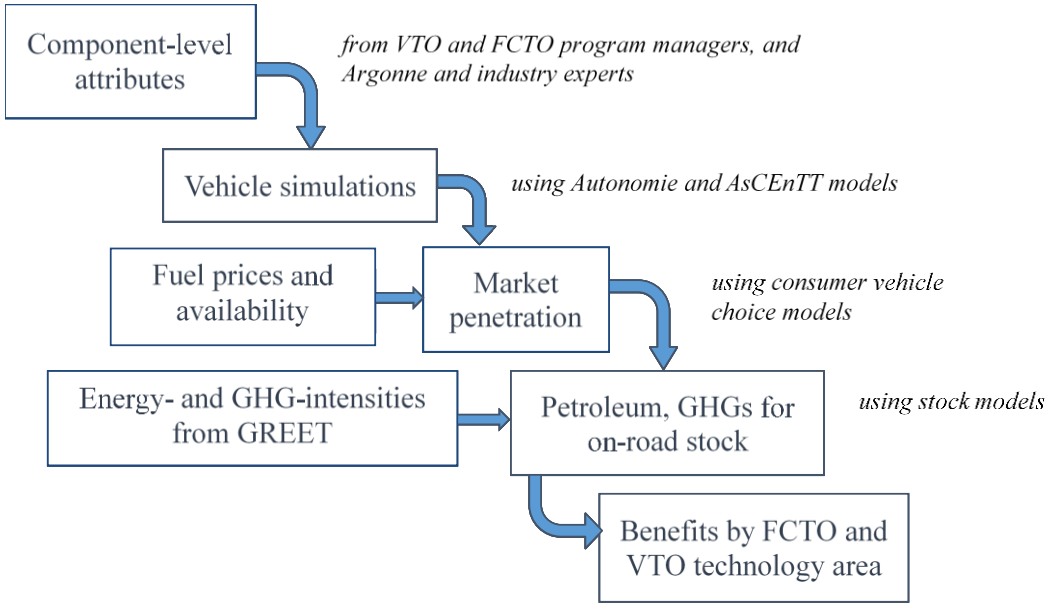


Source: http://cta.ornl.gov/data/

publication

ANL: VTO/FCTO Benefits Analysis now online

This report documents the estimated benefits of successful development and implementation of advanced vehicle technologies, comparing a case with completely successful implementation of Vehicle Technologies Office (VTO) and Fuel Cell Technologies Office (FCTO) technologies (Program Success Case) to a future in which there is no contribution after Fiscal Year 2017 by the VTO or FCTO to these technologies (No Program Case).

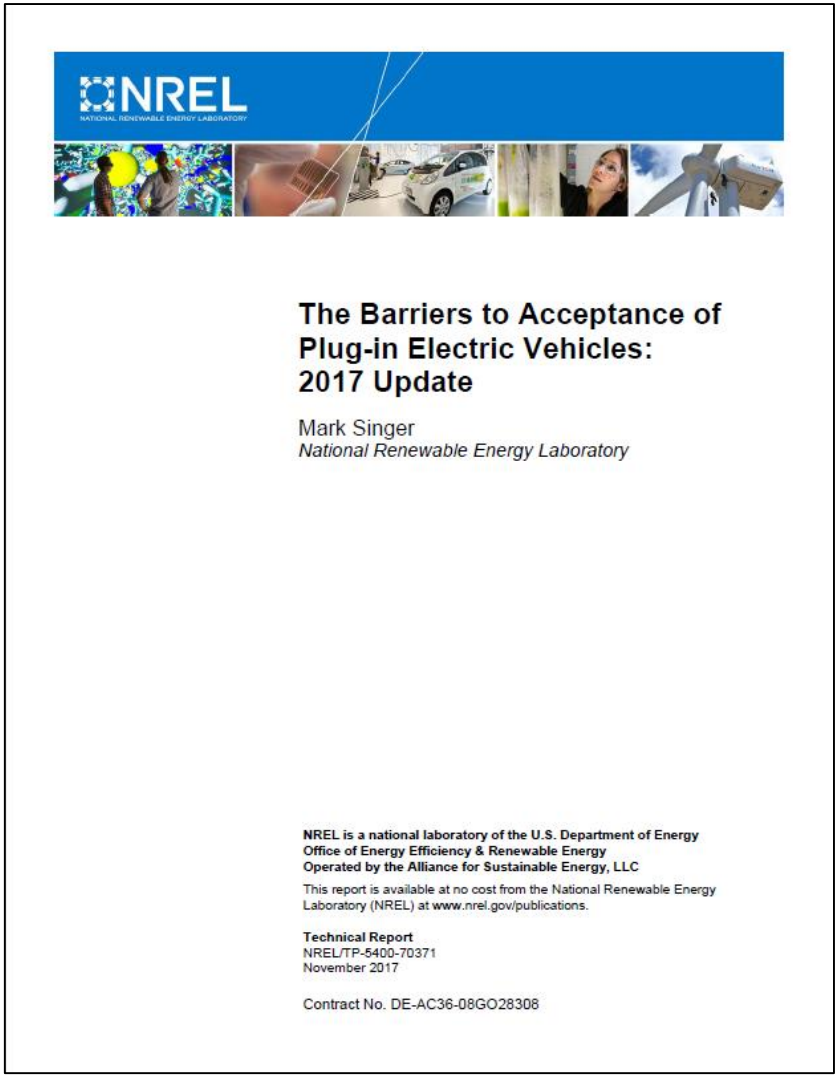


Source: https://www.osti.gov/scitech/biblio/1410412-vehicle-technologies-fuel-cell-technologies-office-research-development-programs-prospective-benefits-assessment-report-fiscal-year

publication

NREL: *The Barriers to Acceptance of Plug-In Electric Vehicles: 2017 Update* is now online

Researchers at the National Renewable Energy Laboratory detailed public sentiments toward issues surrounding plug-in electric vehicles. This report is the third in a series of annual studies tracking consumer attitudes toward plug-in electric vehicles.



Source: https://www.nrel.gov/docs/fy18osti/70371.pdf

publication

VTO: *Enabling Fast Charging: A Technology Gap Assessment* is now online

Researchers at Idaho National Laboratory teamed with Argonne National Laboratory and the National Renewable Energy Laboratory to identify technical gaps to implementing an extreme fast charging network in the United States. This report highlights technical gaps at the battery, vehicle, and infrastructure levels.

Source: https://energy.gov/eere/vehicles/downloads/enabling-extreme-fast-charging-technology-gap-assessment

summary observations

energy	Transportation responsible for 70% of petroleum usage in U.S.; U.S. petroleum production and worldwide consumption set to grow through 2050
automotive	PEV market projected to grow rapidly in U.S. and worldwide
tech/enviro	VTO R&D program success can reduce petroleum consumption and reduce consumer fuel costs; extreme fast charging can change ideas for vehicle design
opinion/policy	PEV charging infrastructure is viewed as important component of purchase behavior; MaaS can reduce travel demand and oil consumption

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summary